The University of Chicago

TRANSFER OF TRAINING IN WHITE RATS UPON VARIOUS SERIES OF MAZES

A DISSERTATION
SUBMITTED TO THE FACULTY
OF THE OGDEN GRADUATE SCHOOL OF SCIENCE
IN CANDIDACY FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

DEPARTMENT OF PSYCHOLOGY

BY
RUTLEDGE THORNTON WILTBANK

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I. INTRODUCTION

The object of these experiments, stated in general terms, was to study the kind and the degree of transfer of training in white rats which were allowed to learn a maze after they had learned, either completely or partially, one or more other mazes. Specifically, the object was to find out:

1. Whether there was transfer of training between a pair of mazes which were learned completely one after the other, and if so whether it was positive or negative. These expressions, "positive transfer" and "negative transfer," are familiar to those interested in this phase of psychological research; but it may not be useless to remark, for the sake of some chance reader, that by the former is meant that the mastery of one or more mazes renders easier the mastery of a subsequent one, while by the latter is meant that the mastery of one or more mazes renders more difficult the mastery of a subsequent one.
2. Whether, if either positive or negative transfer is present, it will persist through a series of mazes; and whether, if both present and persistent, it will also be cumulative.
3. The effect upon the learning of a maze of having partially learned a preceding maze.
4. The effect of the complete learning of a maze upon the mastery of another maze already partially learned.
5. Whether it is more advantageous to learn two mazes in succession; or to partially learn one, then completely learn the other, and finally perfect the learning of the former.
6. The effect upon the relearning of a maze of having learned four intervening mazes between the original learning of the maze and its relearning.

Diagrams of the mazes are presented in Plate I, figs. 1–5. In all the mazes except C the blind alleys were twenty

PLATE I

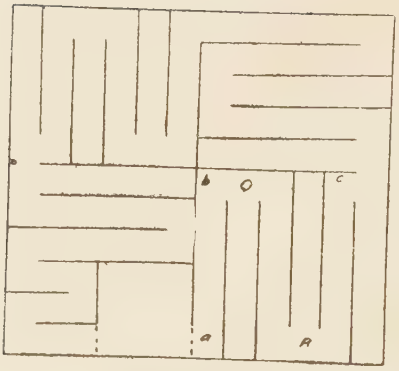

FIG. 1
MAZE A

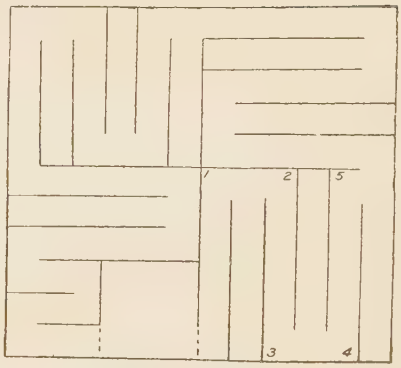

FIG. 2
MAZE B

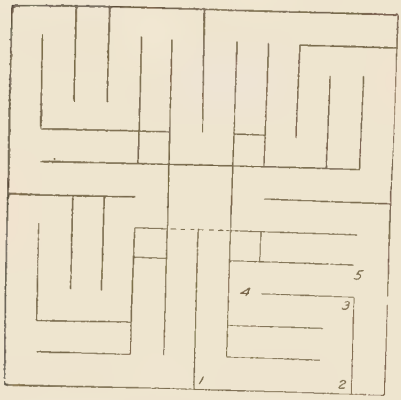

FIG 3
MAZE C

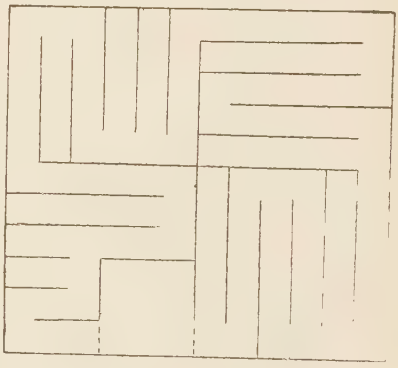

FIG 4
MAZE D

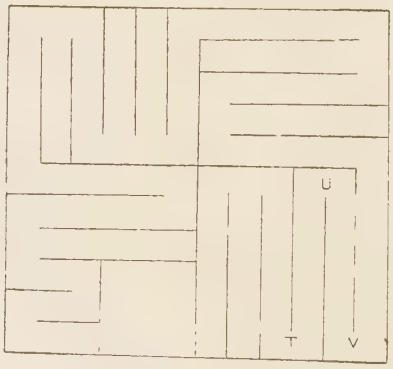

FIG 5
MAZE E

inches long, four inches wide and five inches deep. In the C maze they were thirteen inches long, four inches wide and four inches deep. The mazes were built of half-inch boards, the partitions between the runways in each section being of metal, although the partitions between the sections themselves were of wood. By a section is here meant one of the four main divisions of the maze, in which in all the mazes except C the blind-alleys run in the same direction relative to the observer. By a runway is meant one length of the maze, such as *a*—*b* in maze A, whether it forms part of the true pathway or constitutes a blind alley. The terms, "true pathway" and "blind alley," are open to no ambiguity. The mazes were painted black without and within, and were covered with glass tops.

The rats were between two and three months of age at the beginning of the particular experiment in which they were used. About one third of them were born in the laboratory where the experiments were carried on, and the remainder were obtained elsewhere. The rats were allotted to the various groups in a thoroughly promiscuous way, so that the groups approximated unselected collections. They were fed in the food-box of the maze every day for a week before they were introduced into the maze proper. They were given one trial a day for the first five days, and afterwards two trials a day, one in the forenoon and one in the afternoon. They were fed for two minutes after the trial in the forenoon and for five minutes after the trial in the afternoon. The food was bread and milk with an occasional allowance of sunflower seed. The rats were transferred from one maze to another by groups. Those individuals in a group which learned a maze earliest were still given one trial a day upon the same maze until all had learned it.

Records were kept of the number of trials necessary to learn to run a maze four times out of five without an error, of the errors made during the course of learning and of the time required for each trial. The only errors that were counted were those made by the rat running into blind alleys while moving in the forward direction,

i.e., along the true pathway toward the food-box. These are the only errors which become fixed, and the actual task of the rat, stated in negative terms, is to overcome the tendencies to enter blind alleys while moving in the forward direction. The time was taken with a stop-watch, and was reckoned from the moment when the rat was introduced into the maze until it reached the food-box.

The groups contained the following numbers of rats and proportions of males and females:

Group 1: 8 rats—4 males, 4 females
Group 2: 10 rats—5 males, 5 females
Group 3: 10 rats—6 males, 4 females
Group 4: 9 rats—5 males, 4 females
Group 5: 10 rats—6 males, 4 females

II. TRANSFER OF TRAINING BETWEEN PAIRS OF MAZES

The Positive Nature of the Transfer

An experiment to discover whether there was transfer of training when white rats which had learned one maze were carried over to another, and whether this transfer if present was positive or negative, was performed by Webb.[1] He effected transfers between ten pairs of mazes, in five of which the first maze remained the same, while the second maze in each pair was different from all the rest; and in five of which the first maze in each pair was different from all the rest and the second maze remained the same; so that the order of the transfers was from A to B, from A to C, from A to D, from A to E, from A to F; and from B to A, from C to A, from D to A, from E to A, from F to A. He found in every case that the number of trials required, the total number of errors made per rat and the total time consumed per rat were less for a group learning a given maze as its second to be learned than for the group that learned the given maze as its first. He is of the opinion that the evidence furnished by his experiments both with rats and with humans is strongly in favor of the presence of positive transfer. There was no accounting for these savings on the ground of chance or of group-differences; and, moreover, Webb constructed his mazes with the express purpose of rendering the conditions as favorable as possible for negative transfer.

The present experiment was designed to further test this matter of transfer as between pairs of mazes, using mazes of another pattern and in a different arrangement from those of Webb's. The results of this experiment corroborate the results of Webb's with regard to the presence and the nature of the transfer. The percentages of transfer were computed on the same basis as Webb's—that of the

[1] Webb: Transfer of Training and Retroaction. *Psych. Rev. Mon. Sup.* Vol. 24 No. 3.

average number of trials required to learn the maze, of the total number of errors and the total time per rat. The percentages are given in table 1.

TABLE 1

PERCENTAGES IN SAVINGS IN TRIALS, ERRORS AND TIME IN TRANSFERS BETWEEN TWO MAZES

	Trials	Errors	Time
A to B	59	88	95
B to C	33	49	84
C to D	27	54	57
D to E	69	93	89
E to A	20	65	89
E to D	15	54	49

Although the present experimenter did not try, as did Webb, to devise mazes which would differ so much from one another that the learning of one would exert a detrimental influence upon the learning of the other, nevertheless an examination of plate I, figs. 1 to 5, will disclose that there were marked differences between certain of them. Consider for example mazes B and C, and note the differences in the number, length and arrangement of the blind-alleys. In the first section of maze B, the animal at the end of the first runway turns to the right, but in the corresponding section of C it turns to the left. In B immediately after this there is a blind alley to the right, while in C there is none either to the right or left. After the second turn in C, the animal encounters a blind alley to the left; after the second turn in B, it follows the true pathway. At the fifth turn in C, the animal faces a situation different from any to be met in B, for not only is it at this point in C far more likely to meet the true pathway at a right angle, but there is a blind alley at its left immediately as it turns into the true pathway, a similarly placed one being lacking in B. An examination of the other three sections of the mazes will multiply discrepancies of this kind.

Again, consider the differences between A and E. In the first section of the former, the true pathway consists of three runways and the connecting runways, Q and R;

in the first section of E, there are five runways in the true pathway, and there is only one connecting runway, for at T, U and V the animal passes directly from one runway into another, although instead of turning at about a right angle to do so it must turn through 180 degrees. In the first section of A, there are three blind alleys, and in the corresponding of E there is but one. In the second section of E, the true pathway turns abruptly to the left at the entrance to the section, while in A a blind alley opens at this place. In the third section of E, two blind alleys are placed side by side; in the third section of A the blind alleys alternate. In the fourth section of E, the entering animal turns into the true pathway to the left; in the corresponding section of A, there is a blind alley to the left. But there was positive transfer as between these two mazes, judged by all three criteria.

The Effect of Identical Parts

In order to discover whether the presence of identical parts would affect the kind or the degree of transfer, the first sections of mazes A and B were made alike, and also the third sections of mazes D and E. The savings in trials and errors in the transfers between these mazes with identical parts were notably greater than in the transfers between the mazes without identical parts, as may be seen by reference to table 1. The saving in time in the transfer between A and B was the largest of all the time-savings, but that between D and E was equalled by that between E and A.

If the greater positive transfer in the case of the mazes with identical parts was due to the presence of the identical parts,—and it would seem too large to dismiss as merely fortuitous,—still it is not plain that this greater transfer was brought about within the identical parts themselves. It would seem reasonable to maintain that, if the presence of the identical part in the second maze exerted a favorable influence upon the learning of the maze, the benefit would be most likely to appear in this identical part, although it is conceivable that the beneficial effect might appear in some other part of the maze. For the purpose

of finding out whether there was a greater saving in this identical part of maze B than in the other sections, the distribution of errors within the four sections of maze B made by the control-group and by the trial-group may be compared. The average number of errors per rat made by the control-group, group 2, in the four sections of B, and the average number made by the trial-group, group 1, which had already learned maze A, are given in table 2, together with the percentages of savings made by group 1.

TABLE 2

THE AVERAGE NUMBER OF ERRORS PER RAT MADE BY GROUPS 2 AND 1 IN THE SECTIONS OF MAZE B, AND THE PERCENTAGES OF SAVINGS

	Sec. 1	Sec. 2	Sec. 3	Sec. 4
Group 2	16.5	9.4	13.9	5.5
Group 1	1.7	.9	.8	3.8
Savings by Group 1	89	90	94	31

While group 1 effected a saving in the first section of 89 per cent, the savings in the second and third sections were still larger. It cannot be argued on the *prima-facie* evidence, therefore, that the saving in the identical part was due to the fact of this identity, when the savings in sections dissimilar from the corresponding sections of maze A were even larger. It might be expected that much confusion would arise at the entrance of the second section, inasmuch as the animal had gained undoubtedly as much momentum in the first section of the second maze as in the corresponding section of the first maze, and at the entrance to the second section of the maze it encounters quite a different pattern. Contrary to any preconception, however, the group effected as great a saving in the second section as in the first. In connection with this fact, it may be noted—as has been shown by Webb[2] and is shown also in one of the experiments now being reported[3]—that an animal brings over from the learning of one maze to the learning of another some factors making for positive transfer and some making for negative. There is, accord-

[2] Webb: *op. cit.* p. 52.
[3] *Infra*, p. 18, ff.

ing to the view adopted here as a result of the observations made in the course of these experiments, a practise in error-elimination which is useful and which an animal passing from one maze-learning to another enjoys, so that this animal may be expected to display a greater facility in the the dropping of errors in the second maze than an animal learning this maze as its first. But among the specific habits, including entrance into some runways and the avoidance of others, there will be some that aid the learning and some that deter it; and an instance of the latter may be found in the transfer now under consideration. The group trained in the first maze had learned to pass a blind alley on its left upon entering the fourth section and then to turn into the next runway, which formed a part of the true pathway. When transferred to the second maze, there was no blind alley at the left immediately on entering this section, so that no difficulty was experienced here; but instead of the adjoining runway being a part of the true pathway it was a blind alley, and as a consequence the trial-group made 53 per cent of the total number of errors in this section, where the control-group made but 14 per cent.

It is impossible to predict, with regard to the factors making for positive and for negative transfer, how they will interact in a given situation. It would seem that, in the second of the two mazes involved in the present comparison, the tendency to turn into the blind alley in the fourth section is so deeply implanted, as a result of the learning of the former maze, that any general habit of error-elimination is nearly if not completely suppressed; while on the contrary there are no specific habits in the second and third sections so strongly formed as to counteract the working of the general elimination activity, and the results of this activity were so great that it effected in these sections savings larger than in the identical part.

Turning to the other mazes which contained identical parts, these mazes being the D and E and the parts the third section, we find that positive transfer was evident in the learning of the E maze by the group which had first learned the D maze, and that the greatest saving was effected in the identical part, although the saving in

the first section was nearly as great. The distribution of errors in the various sections of the E maze, and the percentages of savings are given in table 3.

TABLE 3

THE AVERAGE NUMBER OF ERRORS PER RAT MADE BY GROUPS 5 AND 4 IN THE SECTIONS OF MAZE E, AND THE PERCENTAGES OF SAVINGS

	Sec. 1	Sec. 2	Sec. 3	Sec. 4
Group 5 (Control)	11.1	11.7	8.7	.4
Group 4 (Trial)	.33	1.7	.11	.11
Savings by Group 4	97	85	99	72

The situation in maze E differs from the situation in B, in that the identical part is not encountered in the former until the animal has run through two sections which differ from the first two of the maze which he has already learned; so that in the situation presented in the B maze the question was not only as to whether the animal would retain the habit acquired in the first section of the maze in which it was first run, but also as to whether there would be any disconcerting effect from meeting the strange second section after travelling the familiar first one; while in the situation presented in the E maze the transition was from a pathway unfamiliar at the beginning and through half of its whole length to a section which had been learned before. Although the saving in the third section was 99 per cent, this was but little more than the saving in the first section. There would seem to be no ground for the assertion that, if the presence of the identical part in the two mazes results in the more expeditious learning of the second maze, this is due to the saving of errors in the identical part.

It might be contended that the comparison ought to be made between the average number of errors and percentage of saving in the identical part and the average errors and savings of the other three sections taken together, instead of being considered severally as above. When this method is followed, it is found that the average number of errors per rat made in the dissimilar sections of maze B was 1.8 as compared with the average of 1.7 in the identical part, and that the average saving of the

dissimilar sections was 71.7 per cent as compared with 89 in the identical part. The same method applied to maze E discloses that the average number of errors in the dissimilar sections was .71 and the average saving 85 per cent as compared with .11 and 99 in the identical part. It may be remarked that the smaller average savings for the three dissimilar sections were due in the case of both mazes principally to the low records of the fourth section; to which a defender of this method might reply that the low gains in the fourth sections may have resulted from the same cause as the high gains in the identical parts: namely, the presence of the identical part, which exerted more of a beneficial effect in the learning of other sections than it did in the learning of the fourth. But we have seen reason to believe that the smaller gain in the fourth section of the B maze was due to a peculiarity of its pattern in connection with the maze-habit acquired in A; and the smaller gain in the fourth section of E as compared with D may be explicable according to the same principle.

The Dependence of Transfer upon the Relative Difficulty of the Two Mazes

The query is a logical one, whether as between mazes of different degrees of difficulty it matters from the point of view of savings if the more difficult or the less difficult is learned first.

Two of the transfers in this experiment were from the harder to the easier maze, judging by the records of the control-groups; and four were from the easier to the harder. In the case of one of the transfers from the harder to the easier, the saving in errors was less than in any of the transfers from an easier to a harder maze, the saving in trials was less than in two of these transfers, and the saving in time was also less than in two of these transfers, the computations being on both the basis of the average total number of errors and the average total time per rat and the basis of the average errors and the average time per trial. In the case of the other transfer from a harder to an easier maze, the savings in trials and in errors were greater than in any of the transfers from an easier to a

harder maze, judging both by the average total errors and the average total time per rat and by the average number of errors and the average time per trial; and the saving in time was less than the saving in one of the transfers from an easier to a harder maze, according to the average total errors and average total time per rat, and less than the saving in two of these transfers, according to the average number of errors and the average time per trial.

TABLE 4

PERCENTAGES OF SAVINGS IN TRANSFERS FROM LESS DIFFICULT TO MORE DIFFICULT AND FROM MORE DIFFICULT TO LESS DIFFICULT MAZES, ON THE BASIS OF THE AVERAGE TOTAL ERRORS AND AVERAGE TOTAL TIME PER RAT

From the Less to the More Difficult				From the More to the Less Difficult			
	Trials	Errors	Time		Trials	Errors	Time
From A to B...	59	88	95	From B to C....	33	49	84
From C to D...	27	54	57	From D to E...	69	93	89
From E to A...	20	65	89				
From E to D...	15	54	49				

TABLE 5

PERCENTAGES OF SAVINGS IN TRANSFERS FROM LESS DIFFICULT TO MORE DIFFICULT AND FROM MORE DIFFICULT TO LESS DIFFICULT MAZES, ON THE BASIS OF THE AVERAGE NUMBER OF ERRORS AND THE AVERAGE TIME PER TRIAL

From the Less to the More Difficult				From the More to the Less Difficult			
	Trials	Errors	Time		Trials	Errors	Time
From A to B...	59	70	88	From B to C....	33	33	78
From C to D...	27	37	41	From D to E...	65	77	69
From E to A...	20	53	86				
From E to D...	15	46	40				

It will be seen from the figures in tables 4 and 5 that, although the average savings are higher when the transfer is from the harder to the easier maze, there is no ground for the statement that these savings are in every instance higher than when the transfer is from the easier to the harder. The transfer from the easier to the harder may be greater, as we may note by comparing the transfer between A and B with that between B and C.

III. TRANSFER OF TRAINING THROUGH SERIES OF MAZES

The Persistence of the Transfer

If we accept the statement that there is positive transfer of training when rats are carried over from one maze completely learned to another which is then also completely learned, the question arises as to whether the transfer of training will persist and retain its positive character if the learning is continued through a series of mazes. It might be presupposed with some plausibility that habits acquired in situations which present marked peculiarities in the midst of general resemblances, as do the situations in the various mazes, would conflict with one another in such a way that the transfer would cease to be positive. On the other hand, it might be presupposed with perhaps equal plausibility that in these situations practise tends toward perfection, and the ability which an animal has to thread the maze may consequently be expected to improve in proportion to the number of mazes it learns to run.

It was to throw light upon this question that the present experiment was undertaken. The five groups of rats were allowed to continue their learning through series of mazes, each group learning one series. The series were composed of the same five mazes, but the mazes were learned in a different order by each group, according to the scheme presented in table 6, in which the letters represent mazes and the numbers groups of rats.

TABLE 6

THE ORDER IN WHICH VARIOUS SERIES OF MAZES WERE LEARNED BY VARIOUS GROUPS

Mazes	A	B	C	D	E	A	B	C	D
Group	1	1	1	1	1	..	..	..	..
	..	2	2	2	2	2	..	..	..
	..	..	3	3	3	3	3	..	..
	..	..	..	4	4	4	4	4	..
	..	..	..	..	5	5	5	5	5

In pursuance of this method, there were twenty-five maze-learnings, in twenty of which evidence might be sought as to whether the positive transfer persists. Attention is drawn to the fact that the first group to learn a given maze constituted a control-group for that maze. The records of the groups upon these series of mazes are given in tables 7 to 16. The average number of trials necessary to learn a maze is given, and in connection with it the mean variation of the individual rats from this average; then the percentages of transfer for each maze are given, these being computed by comparing the record of the trial-group with that of the control-group in this particular maze. The same method is followed with respect to errors and time, and these are reckoned both on the basis of the average total per rat and on that of the average per trial. The percentages of transfer are shown graphically in figures 6, 7, and 8.

TABLE 7

THE AVERAGE NUMBER OF TRIALS PER RAT IN THE LEARNING OF A SERIES OF MAZES

	Group 1	Group 2	Group 3	Group 4	Group 5
Maze A..	26.62± 6.87	.....	.....	.....	.....
Maze B..	11.62± 5.28	28.70± 6.66	.....	.....	.....
Maze C..	9.75± 3.31	12.20± 4.14	16.20±7.24	.....	.....
Maze D..	25.56±12.67	27.60±10.93	18.00±8.03	24.67±7.24	.....
Maze E..	4.00	4.40± .56	7.30± .49	7.11±3.88	23.10±7.10
Maze A..	6.62± 3.56	6.40± 1.92	6.50±2.32	6.89±3.23	21.40±8.95
Maze B..	.....	7.50± 3.91	13.20± .67	11.44±3.06	19.00±4.91
Maze C..	.....	.....	6.20±1.84	9.00±2.64	7.00±1.51
Maze D..	.....	.....	.....	8.89±3.96	22.10±4.87
Maze E..	.....	.....	.....	.....	5.00± .83

TABLE 8

THE PERCENTAGES OF TRANSFER OF TRAINING IN TRIALS THROUGH A SERIES OF MAZES

	Group 1	Group 2	Group 3	Group 4	Group 5
Maze B..	59	....	....	....	....
Maze C..	39	33	....	....	....
Maze D..	—3.58	—12	27	....	....
Maze E..	83	81	68	69	....
Maze A..	75	76	75	74	20
Maze B..	....	74	54	60	34
Maze C..	....	....	62	44	57
Maze D..	....	....	....	64	4.33
Maze E..	....	....	....	....	78

TABLE 9

THE AVERAGE TOTAL NUMBER OF ERRORS PER RAT IN THE LEARNING OF A SERIES OF MAZES

	Group 1	Group 2	Group 3	Group 4	Group 5
Maze A. .	48.45±13.52	.....	.....	.....	.....
Maze B. .	8.15± 2.52	68.88±36.52	.....	.....	.....
Maze C. .	6.82± 2.42	14.50± 6.20	28.35±8.72	.....	.....
Maze D. .	26.58±13.27	22.36±10.61	21.42±9.38	46.63±14.96	.....
Maze E. .	0	.31± .12	1.31± .95	2.20± 1.26	31.88±12.27
Maze A. .	1.31± .91	1.22± .70	1.75±1.20	2.07± .92	16.69± 6.56
Maze B. .	.....	3.97± 1.30	6.74±3.29	9.27± 3.55	18.05± 5.99
Maze C. .	.....	.....	1.92± .82	7.29± 4.45	3.64± 1.29
Maze D. .	.....	.....	.....	4.53± 2.21	23.87± 8.45
Maze E. .	.....	.....	.....	.....	.90± .72

TABLE 10

THE PERCENTAGES OF TRANSFER OF TRAINING, ON THE BASIS OF THE AVERAGE TOTAL NUMBER OF ERRORS PER RAT, IN THE LEARNING OF A SERIES OF MAZES

	Group 1	Group 2	Group 3	Group 4	Group 5
Maze A. .	..	..	..	..	..
Maze B. .	88	..	..	..	..
Maze C. .	76	49	..	..	..
Maze D. .	43	52	54	..	..
Maze E. .	100	99	96	93	..
Maze A. .	97	97	96	96	65
Maze B. .	..	94	90	87	74
Maze C. .	..	..	93	74	87
Maze D. .	..	..	..	90	49
Maze E. .	..	..	..	..	97

TABLE 11

THE AVERAGE TOTAL TIME PER RAT IN THE LEARNING OF A SERIES OF MAZES

	Group 1	Group 2	Group 3	Group 4	Group 5
Maze A. .	50.05±29.74	.....	.....	.....	.....
Maze B. .	4.65± 2.27	93.85±49.36	.....	.....	.....
Maze C. .	5.75± 3.30	12.71± 9.17	77.92±39.49	.....	.....
Maze D. .	9.20± 4.42	15.46± 8.41	16.20± 7.17	37.50±19.45	.....
Maze E. .	1.56± .38	1.53± .34	3.36± 1.57	3.27± 1.79	30.72±16.20
Maze A. .	1.39± .81	1.60± 1.02	2.01± .80	1.93± .90	5.56± 1.48
Maze B. .	.....	2.02± 1.51	4.22± 1.23	3.09± 1.04	4.75± 1.44
Maze C. .	.....	.....	7.56± 4.81	17.73±10.37	4.55± 1.38
Maze D. .	.....	.....	.....	6.49± 5.98	5.52± 2.13
Maze E. .	.....	.....	.....	.....	2.15± 1.05

TABLE 12

THE PERCENTAGES OF TRANSFER OF TRAINING, ON THE BASIS OF THE AVERAGE TOTAL TIME PER RAT, IN THE LEARNING OF A SERIES OF MAZES

	Group 1	Group 2	Group 3	Group 4	Group 5
Maze A. .	..	..	..	..	..
Maze B. .	95	..	..	..	..
Maze C. .	93	84	..	..	..
Maze D. .	75	59	57	..	..
Maze E. .	95	94	89	89	..
Maze A. .	97	97	97	96	89
Maze B. .	..	96	96	97	96
Maze C. .	..	..	90	77	94
Maze D. .	..	..	..	83	84
Maze E. .	..	..	..	..	93

TABLE 13

THE AVERAGE NUMBER OF ERRORS PER TRIAL IN THE LEARNING OF A SERIES OF MAZES

	Group 1	Group 2	Group 3	Group 4	Group 5
Maze A. .	1.82±.33	.....	.....	.....	.....
Maze B. .	.71±.30	2.40±.40	.....	.....	.....
Maze C. .	.70±.35	1.18±.54	1.75±.40	.....	.....
Maze D. .	1.04±.34	.81±.23	1.19±.26	1.89±.37	.....
Maze E. .	0	.07±.04	.18±.21	.31±.17	1.38±.32
Maze A. .	.17±.16	.19±.01	.27±.17	.30±.24	.78±.24
Maze B. .	.....	.53±.39	.51±.28	.81±.13	.95±.21
Maze C. .	.....	.....	.31±.21	.81±.34	.52±.25
Maze D. .	.....	.....	.....	.51±.26	1.08±.30
Maze E. .	.....	.....	.....	.....	.18±.08

TABLE 14

THE PERCENTAGES OF TRANSFER OF TRAINING, ON THE BASIS OF THE AVERAGE NUMBER OF ERRORS PER TRIAL, IN THE LEARNING OF A SERIES OF MAZES

	Group 1	Group 2	Group 3	Group 4	Group 5
Maze A. .	..	..	..	..	..
Maze B. .	70	..	..	..	..
Maze C. .	59	33	..	..	..
Maze D. .	45	58	37	..	..
Maze E. .	100	95	87	77	..
Maze A. .	91	90	80	84	53
Maze B. .	..	78	79	65	60
Maze C. .	..	..	82	54	71
Maze D. .	..	..	..	76	43
Maze E. .	..	..	..	..	87

TABLE 15

THE AVERAGE TIME PER TRIAL IN THE LEARNING OF A SERIES OF MAZES

	Group 1	Group 2	Group 3	Group 4	Group 5
Maze A. .	1.88±1.23	.....	.....	.....	.....
Maze B. .	.40± .12	3.27±2.12	.....	.....	.....
Maze C. .	.59± .13	1.05± .68	4.81±1.77	.....	.....
Maze D. .	.36± .16	.56± .40	.90± .41	1.52± .77	.....
Maze E. .	.39± .10	.37± .09	.46± .14	.46± .19	1.33 ±.68
Maze A. .	.21± .04	.25± .12	.31± .06	.28± .08	.26±.03
Maze B. .	.....	.27± .05	.32± .06	.27± .05	.25±.02
Maze C. .	.....	.....	1.38± .97	1.97±1.62	.65±.12
Maze D. .	.....	.....	.....	.73± .67	.25±.06
Maze E. .	.....	.....	.....	.....	.43±.13

TABLE 16

THE PERCENTAGES OF TRANSFER OF TRAINING, ON THE BASIS OF THE AVERAGE TIME PER TRIAL, IN THE LEARNING OF A SERIES OF MAZES

	Group 1	Group 2	Group 3	Group 4	Group 5
Maze A. .	..	..	..	..	..
Maze B. .	88	..	..	..	..
Maze C. .	88	78	..	..	..
Maze D. .	76	45	41	..	..
Maze E. .	71	73	65	65	..
Maze A. .	89	86	30	85	86
Maze B. .	..	92	90	92	90
Maze C. .	..	..	70	59	54
Maze D. .	..	..	..	52	83
Maze E. .	..	..	..	..	68

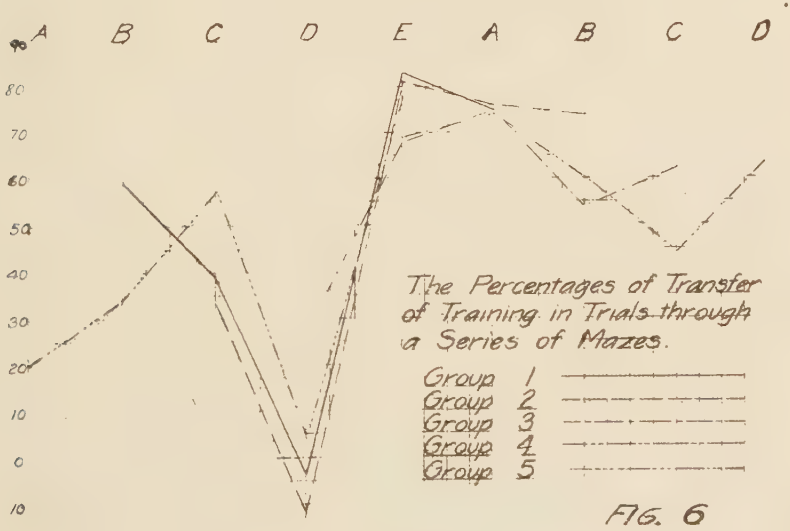

FIG. 6

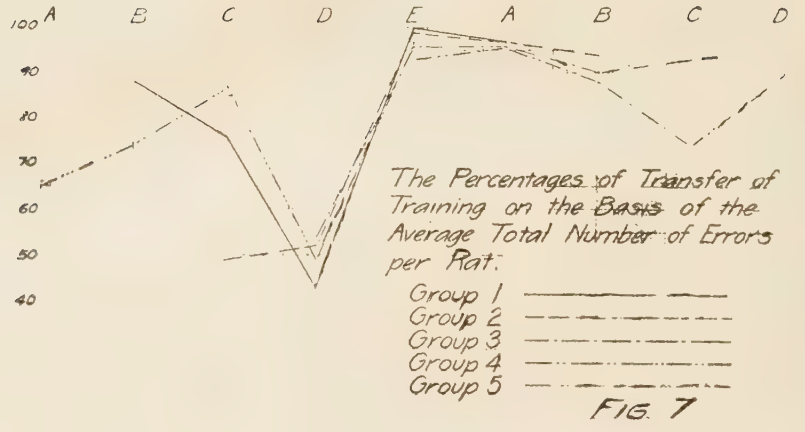

FIG. 7

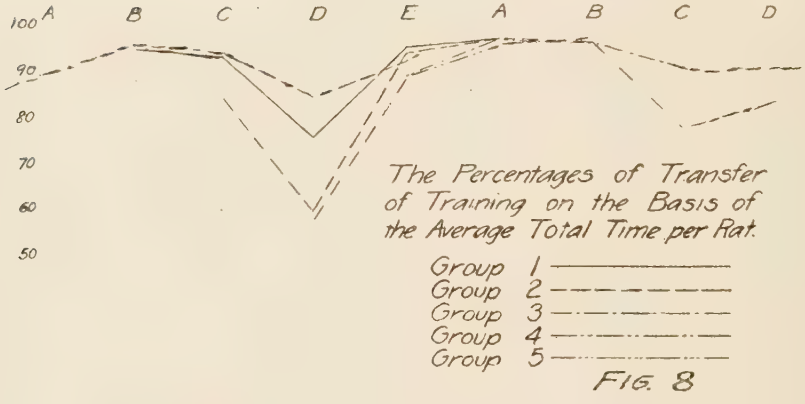

FIG. 8

An examination of tables 7 to 16 will reveal the fact that there was positive transfer manifest throughout the various series of maze-learnings with the exception of the learning of maze D by groups 1 and 2, as judged by the criterion of trials, the former group requiring an average of 3.58 per cent more trials than did the control-group upon this maze, and the latter requiring 12 per cent more (Tables 7 and 8).

In examining the records made by groups 1 and 2 in maze D for the purpose of explaining these occurrences of negative transfer, the outstanding fact brought to light is that it is the number and persistence of errors made in the first blind alley of maze D which account for the nega-

tive transfer. This fact comes out upon a comparison of the records of the control-groups and trial-groups concerned. Out of 420 errors made by the control-group in learning the maze, 102 were made in the first blind alley, and the rest were distributed among the other blind alleys. Out of a total of 223 errors made by group 2 in this maze, 166 were made in the first blind alley; and out of a total of 212 made by group 1, 126 were made in the first blind alley. It was the large number of trials necessary to eliminate these errors made in the first blind alley which resulted in the negative transfer, as may be seen from an examination of tables 17 to 20, and figure 9, in which respectively the number of errors and the percentage of errors made in each blind alley by each group are shown.

TABLE 17

THE ERRORS MADE BY GROUP 4 (CONTROL) IN MAZE D, ARRANGED ACCORDING TO BLIND ALLEYS AND TRIALS

Blind Alleys	1	2	3	4	5	6	7	8	9	10	11
Trial 1	5	2	2	4	1	1	2	1	2	2	2
2	5	2	1	3	1	1	2	2	1		
3	4	1	2	5	1	1	2	3	4		2
4	6	1	5	4	3			3	4		
5	5	2	5	3	2		1		3		
6	4	2	4	1	2		2	1	4		2
7	4	2	2	1	3	1	1	2	1		
8	5	3	3	3	1		2	1	3		
9	3	2	3	4	4	1	2	4	3		
10	6	4	2	4	2	1	3		3		
11	5	2	3	3	2		1	2	4		
12	7	4	1	2	3		3	2	3		
13	5	3	2	2	3		4		2		
14	3	2		3	1		1		3		
15	3	3		3	1		2		1		1
16	4	1			1		1		3		
17	2	2		3	1		1		2		2
18	2	3		2	1				1		1
19	5	2		1							
20	3	1							1		
21	4	2		3			1		1		
22	1	1	2	4	1				1		
23	3			1							
24	1	1		3							
25	2			1			1				
26	1			1							
27	1			1							
28		1		2							
29	1		1	2							
30				3							
31	1	1		1							
32		1		1							
33	1										

TABLE 18

THE ERRORS MADE BY GROUP 3 IN MAZE D, ARRANGED ACCORDING TO BLIND ALLEYS AND TRIALS

Trial	Blind Alleys 1	2	3	4	5	6	7	8	9	10	11
1	14	2	4	2		3	2	1		1	1
2	14	1	1	1	1						
3	7		1	4							
4	6	1	1	2	1		1		2		2
5	4		2	2			2				1
6	4		1	1	1				1	1	1
7	4						1		4		
8	7			1			2		3		
9	5	1					3	1	1		
10	4						3		2		
11	3										
12	5			4			2		2		
13	4						2				
14	4						2				
15	4	1		1							
16	3	1									
17	3			1							
18	2										
19	2			1							
20	1								1		
21	1						1				
22	1			1							
23	1			1							
24											
25	1										
26	1										
27	1										
28	1										
29	1										
30	1										
31	1										
32	1										
33	1										

TABLE 19

THE ERRORS MADE BY GROUP 2 IN MAZE D, ARRANGED ACCORDING TO BLIND ALLEYS AND TRIALS

Trial \ Blind Alleys	1	2	3	4	5	6	7	8	9	10	11
1	4				1	2		1	4	6	1
2	6	1		3					2	3	1
3	8			1			2		1		
4	8			1			2		1		1
5	8			1			1		1		
6	8			1			2		1		1
7	7								1		
8	8								1		1
9	6			1			1				
10	9		1	1			1		1		
11	4	1									
12			1	1							
13	7			1							
14	6			1							
15	6	1									
16	5										
17	4										
18	4										
19	5										
20	3										
21	3										
22	5										
23	4										
24	2										
25	3										
26	1										
27	2										
28	3										
29	2										
30	3										
31	1										
32	2										
33	2										
34	2										
35	1										
36	2										
37	2										
38	2										
39	2										
40	2										
41	2										
42	1										
43	0										
44	1										

TABLE 20

THE ERRORS MADE BY GROUP 1 IN MAZE D, ACCORDING TO BLIND ALLEYS AND TRIALS

Blind Alleys	1	2	3	4	5	6	7	8	9	10	11
Trial 1	9	3			1		2	1	7	2	1
2	9	2		1			2	2	5	2	3
3	5	1					4		4		
4	5	1					2		4		
5	2	1					1		3		
6	6	1			1				3		
7	5		1	1	1		2		2		
8	5		2		1						
9	4						1		1		2
10	5			1			1		2		
11	4			1					3		
12	3			1			1		1		
13	4								1		
14	4										
15	2								1		
16	2										
17	2										
18	2										
19	3										
20	2										
21	2										
22	1										
23	3										
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38	1										
39	1										
40	1										
41	1										
42	1										
43	1										
44	1										
45	1										
46	1										
47	1										
48	1										
49	1										
50	1										
51											
52	1										
53	1										

TABLE 20—(*Continued*)

Blind Alleys	1	2	3	4	5	6	7	8	9	10	11
Trial 54											
55	1										
56	1										
57	1										
58											
59	1										

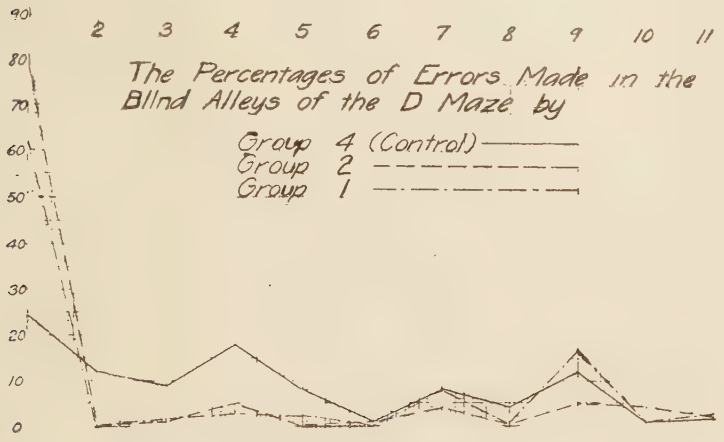


FIG 9

It is apparent that these instances of negative transfer cannot be treated as if the transfer in question were simply that between the C maze and the D maze. The groups exhibiting this negative transfer had learned—one the A and B mazes before the C, and the other the B maze before the C. The fact that, as between the C and the D mazes when no other maze had been learned before C, there was 27 per cent of positive transfer, while the transfer was negative when maze B or mazes A and B were learned before C, would suggest that the final element of the explanation is to be sought in the learning prior to that of the C maze.

The increase of more than 100 per cent in the errors made by group 3 in blind alley 1 of the D maze, as compared with the errors made by the control-group, would seem to have been due to the facts that group 3 came to the maze with the habit already formed of traversing a runway of similar construction to those confronting it on

entering D, and that the behavior of the animals on being placed within the entrance of D accounts for their frequent entrances into blind alley 1. The former of these facts needs no special comment, for the connection between running forward through a series of runways and obtaining food at the end of the journey must be implanted in the animal's neural mechanism by the close of the first maze-learning. Why the animals entered the blind alley so frequently, however, is not to be explained solely on the ground of the dispositions which they brought with them to the maze, but also on the ground of their behavior within the maze itself. It was the almost invariable behavior of the rats,—invariable both as respects the number of rats concerned and the number of trials through which it continued,—to turn immediately on being introduced into the maze and sniff at the door. This brought their bodies into a position in which the likelihood of their entering blind alley 1 was much greater than that of their entering the true pathway, as may be seen by referring to the diagram of the maze, Plate I, figure 4. When they were in this position, it required movement through only a few degrees to the right in order to bring their heads into line with the blind alley or even into the blind alley. In any case, it was a situation similar to that which in the C maze called forth the first of the motor habits eventuating in the animals' obtaining food, and the animals plunged into the blind alley with great speed and great force. After sniffing at the door, it was necessary for them, if they were to enter the true pathway, either to pass close to the blind alley by turning to the right, without being overcome by its solicitation; or else by turning to the left pass through an arc of more than 180 degrees. It is plain that, once the animals turned to the door, their chance random movements would favor decidedly the selection of the blind alley.

The question remains to be dealt with, why this tendency to enter the blind alley should have been so greatly exaggerated in the cases of groups 1 and 2—so greatly, in fact, as to be the cause of the negative transfer. If 52.8 per cent of the errors made by group 3 were made in blind

alley 1, 60 per cent of those made by group 1 and 74 per cent of those made by group 2 were made in the same blind alley. All the conditions under which the three groups learned the maze were the same, and the only difference among the groups was in the number of mazes they had learned before being placed in D. Group 3 had learned one maze, group 2 had learned two mazes, and group 1 had learned three. It would seem therefore that the difference in the records of group 3 on the one hand and of groups 1 and 2 on the other must have been due to some factor or factors acquired prior to the learning of the C maze. Reference to the patterns of the mazes concerned will furnish a clue as to the nature of this factor. In maze C the true pathway proceeds directly from the entrance without necessitating any change in the orientation of an animal that was introduced straight through the entrance; but in mazes A and B the true pathway turns to the left, demanding a turn to the left in an animal so introduced. The marked tendency of the rats in groups 1 and 2 to turn into blind alley 1 in maze D would seem accordingly to come from a habit brought to maze C, leading them to seek the true pathway in the same position which the blind alley occupies in maze D.

It would be reasonable to affirm that, on the basis of the principles adduced to explain the cases of negative transfer, we should look for negative transfer in the group which learned mazes E, A, B and C before learning the E maze, for in the E maze as well as in mazes A and B the true pathway lies to the left of the entrance. It would seem equally reasonable to expect that the tendency to take the first runway to the left of the entrance in maze D would be more pronounced in group 1 than in group 2, and more pronounced in group 5 than in either 1 or 2, since group 5 learned three mazes in which the true pathway takes this course, group 1 learned two, and group 2 learned one. Contrary to these assumptions, we find that the transfer of group 5 on maze D is positive. But it is the least of all the positive transfers, being only 4.33 per cent; and when we examine the distribution of errors according to the blind alleys and the trials, we see the same tendencies

at work as in the case of groups 1 and 2. Of the 239 errors made by the group, 137 were made in the first blind alley, or 56.9 per cent of the total number; and the errors persisted there as with the other groups. In the case of this group, however, the tendencies were not quite sufficient to turn the tide of positive transfer. This reversal of such justifiable expectations as those above might be due to an increase in the number of deviations from the rule of turning to sniff at the door as the rats learned an increasing number of mazes. That there was an increase in these exceptions cannot be asserted, for no record of the number of sniffings was kept; but it would seem probable that the futility of such behavior would lead to its becoming less frequent. It would not take many deviations of this sort from the usual behavior to account for the difference between the 3.58 per cent of negative transfer shown by group 1 and the 4.33 per cent of positive transfer shown by group 5.

The negative instances dealt with above indicate certainly that, when three mazes are learned in succession, the transfer is not a function of the last two mazes alone, but of all three; and they probably indicate that, when four or five are learned in succession, the transfer is not a function of the last two alone, but of all the mazes involved. They also prove—it needs hardly to be remarked—that, although transfer is generally positive, there may be a particular kinaesthetic habit occurring in a particular maze-situation so as to produce negative transfer.

The Question as to Whether the Transfer is Cumulative

The experiment demonstrates that the transfer as between the first and second mazes of a series is positive, and that the transfer as between any other two contiguous mazes of the series is also positive, judging by all the three criteria employed, except in the two negative results in trials. The query which next presents itself is whether this generally persistent positive transfer increases with each additional maze-learning, or in other words whether it is cumulative.

There was no series in which the transfer as estimated by

any one of the criteria was cumulative throughout the series, but there were some instances where there was cumulation for three maze-learnings and one where there was cumulation for four. These are given in table 21.

TABLE 21

CUMULATIVE SAVINGS IN AVERAGE TRIALS, IN AVERAGE ERRORS PER TRIAL AND IN AVERAGE TIME PER TRIAL

Group	Mazes	Percentages of Transfer in Mazes Named
	Savings in Trials	
3	C to D, D to E, E to A	27, 68, 75
5	E to A, A to B, B to C	20, 34, 57
	Savings in Errors	
2	B to C, C to D, D to E	33, 58, 95
5	E to A, A to B, B to C	53, 60, 71
	Savings in Time	
2	C to D, D to E, E to A, A to B	45, 73, 86, 92
4	D to E, E to A, A to B	65, 85, 92

Over against these five instances of cumulation for three mazes and one of cumulation for four, there were eight instances in which the transfer decreased in amount through three maze-learnings. Three of these were in trials, four in errors and one in time. They are presented in table 22.

TABLE 22

SUCCESSIVE DECREASES IN TRANSFER OF TRAINING

Group	Mazes	Percentages of Transfer in Mazes Named
	According to Average Trials	
1	A to B, B to C, C to D	59, 39, —3.58
2	D to E, E to A, A to B	81, 76, 74
4	E to A, A to B, B to C	74, 60, 44
	According to Average Errors per Trial	
1	A to B, B to C, C to D	70, 59, 45
2	D to E, E to A, A to B	95, 90, 78
3	D to E, E to A, A to B	87, 80, 79
4	E to A, A to B, B to C	84, 65, 54
	According to Average Time per Trial	
1	B to C, C to D, D to E	88, 76, 71

When the errors and the time were computed on the basis of the average total per rat, there were six instances in errors and time taken together where the transfer was cumulative for three maze-learnings, and six where it decreased for three maze-learnings in succession. In the case of the errors, the mazes upon which these cumulations and decreases occurred were the same, whether the errors were computed according to one or the other method, except that according to the average per trial there was one more series than according to the other method. But in the case of time, cumulation appeared upon the same two series of three mazes as it did according to the average time per trial and also upon two additional series of three mazes. There was no coincidence in the decreases in time as reckoned by the two methods.

There is no evidence therefore that this generally positive and persistent transfer is also cumulative invariably and continuously; nor, it may be added, that there is a regular and continuous decrease.

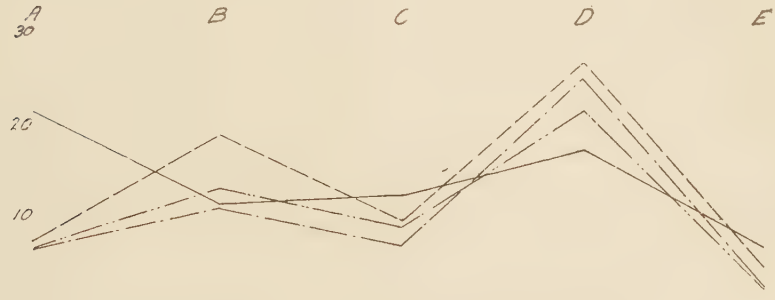
The Effect of Preceding Maze-Learnings upon the Learning of a Particular Maze

In the foregoing discussion, the data are treated from the point of view of the different groups as they proceed to learn the series of mazes, and we have followed the various groups and examined their records to see whether these records show a persistence and a cumulation of positive transfer. But the same data can be considered from another point of view—that of a particular maze, where we can take our position and inquire if this maze can be learned more readily by a group that has had two previous learnings than by a group that has had but one, and if by a group that has had three more readily than by a group that has had two, and so on. The number of trials required by the various groups to learn the various mazes is given in table 23, and figure 10. Disregarding the designations of the groups, which can be obtained by reference to table 6, p. 13, they are treated merely as the groups which were the first, second, third, fourth or fifth to learn a certain maze.

TABLE 23

THE AVERAGE NUMBER OF TRIALS PER RAT REQUIRED IN LEARNING A MAZE BY GROUPS HAVING PREVIOUSLY LEARNED ONE, TWO, THREE, OR FOUR MAZES

	Maze A	Maze B	Maze C	Maze D	Maze E
Group having learned *one* preceding maze	21.40	11.62	12.20	18.00	7.11
Group having learned *two* preceding mazes	6.89	19.00	9.75	27.60	7.30
Group having learned *three* preceding mazes	6.50	11.44	7.00	25.56	4.40
Group having learned *four* preceding mazes	6.40	13.20	9.00	22.10	4.00



The Average Number of Trials per Rat Required in Learning a Maze by Groups Having Previously Learned One or More Mazes.

Group Having Learned One Preceding Maze
" " " Two " " "
" " " Three " " "
" " " Four " " "

FIG. 10

The figures in table 23 show that the groups which have learned more than one maze before attacking another do not necessarily and invariably enjoy any advantage in the learning of the new maze, as compared with the trial-record of the group that came to the maze with but one prior maze-learning. The groups learning maze A showed a nominal increase of savings with the increase in the number of previous maze-learnings, but the group that had had four maze-learnings saved but .1 of a trial as compared with the one having had three, and the one that had had three saved but .4 of a trial as compared with the one having had two. If the group with two previous maze-

learnings showed a large saving relative to the group with one, this is deprived of any significance by the fact that, in the case of the other four mazes, two of them proved easier for the group with one prior learning than for the group with two. A comparison of the groups with three prior learnings and the groups with four discloses the fact that in two instances—namely, in mazes B and C, the groups with three prior learnings learned the maze more readily than the groups with four; and, if there were three instances where the groups with four prior learnings did better than those with three, one of these was but .1 of a trial better. This table might accordingly be brought forward in support of the statement that three maze-learnings are as good as four, measured by the beneficial effect upon the learning of a subsequent maze according to the standard of trials. But the actual differences in these figures representing the number of trials necessary to learn the third and fourth mazes are not large enough to give much weight to such a statement.

The D maze presents the least evidence of any beneficial effect accruing from the learning of preceding mazes, and the principle which is to be invoked in explanation is the one used with reference to the negative figure representing the transfer in trials, as may be seen on pp. 18 ff. The number of trials needed by the groups coming to this maze with two and with three prior learnings was greater than the number made by the control-group, and the number needed by the group coming with four learnings was also high. These figures were all greater than any in the A and B mazes, the control-figures of which show them to be some-

TABLE 24

THE RANKINGS OF THE GROUPS UPON THE MAZES, ACCORDING TO THE AVERAGE NUMBER OF TRIALS PER RAT

	Maze A	Maze B	Maze C	Maze D	Maze E	Av. Rank
Group having learned *four* preceding mazes	1	3	2	2	1	1.8
Group having learned *three* preceding mazes	2	1	1	3	2	1.8
Group having learned *two* preceding mazes	3	4	3	4	4	3.6
Group having learned *one* preceding maze.	4	2	4	1	3	2.8

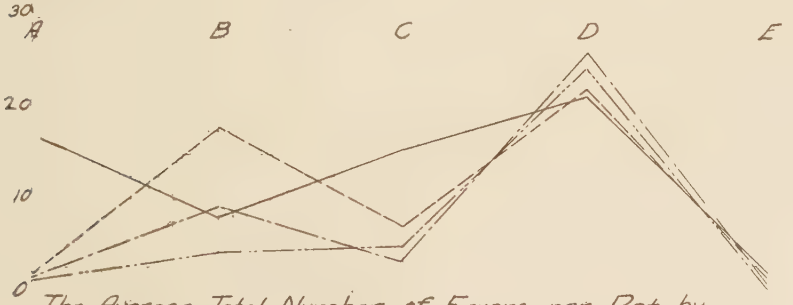
what more difficult mazes. It is the position of blind alley 1 which accounts for this. When the animals came from the C maze, they found themselves in a situation which in the maze or mazes before C had called forth the habit of turning into a runway to the left on entering the maze; and this position in the D maze being occupied by a blind alley which called forth this habit, the learning of the maze was consequently retarded.

The evidence that the average total number of errors per rat tends to decrease as the number of prior maze-learnings increases is more convincing than any figures furnished by the trial criterion in favor of a similar benefit from the latter point of view, as may be seen from an examination of table 25 and figure 11.

TABLE 25

THE AVERAGE TOTAL NUMBER OF ERRORS PER RAT BY GROUPS HAVING PREVIOUSLY LEARNED ONE OR MORE MAZES

	Maze A	Maze B	Maze C	Maze D	Maze E
Group having learned *one* preceding maze	16.69	8.25	15.40	21.42	2.20
Group having learned *two* preceding mazes	2.07	18.05	6.82	22.36	1.31
Group having learned *three* preceding mazes	1.75	9.27	3.64	26.58	.31
Group having learned *four* preceding mazes	1.22	6.73	7.29	23.87	00



The Average Total Number of Errors per Rat by Groups Having Previously Learned One or More Mazes.

Group Having Learned One Preceding Maze
" " " Two " " "
" " " Three " " "
" " " Four " " "

FIG. 11

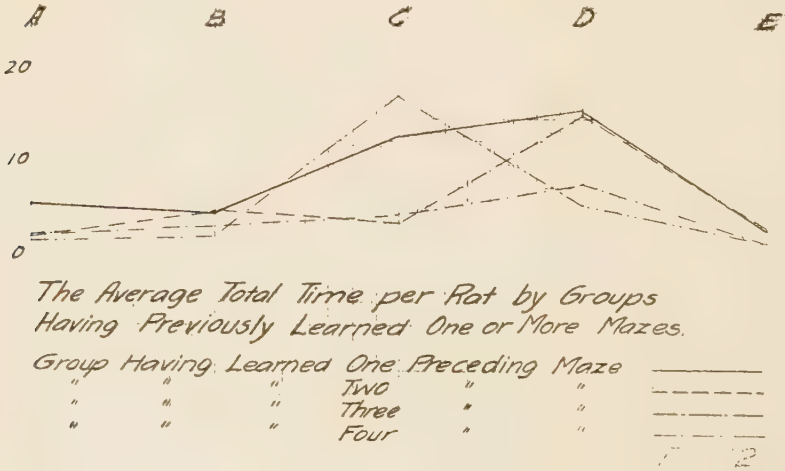
In two mazes, A and E, the average total number of errors per rat decreased with the increase in the number of mazes previously learned, and these decreases were not slight ones, proportionately speaking. If the various groups are ranked upon the mazes according to the average total errors made by the rats of the group, it will be found that the average ranking of the groups having had four prior learnings is highest, the average total errors of the rats in these groups taken together being least; and the groups having had three, two and one prior learnings follow in order. This may be seen in table 26.

TABLE 26

THE RANKINGS OF THE GROUPS UPON THE MAZES, ACCORDING TO THE AVERAGE TOTAL NUMBER OF ERRORS PER RAT

	Maze A	Maze B	Maze C	Maze D	Maze E	Av. Rank
Group having learned *four* preceding mazes	1	1	3	3	1	1.8
Group having learned *three* preceding mazes	2	2	1	4	2	2.2
Group having learned *two* preceding mazes	3	4	2	2	3	2.8
Group having learned *one* preceding maze.	4	3	4	1	4	3.2

According to the average total time per rat, there was only one maze in which this time decreased with the increase in the number of previous maze learnings by groups



coming to the maze—maze A. When the groups were ranked upon the various mazes, the groups with four and those with three previous learnings had the same average ranking, these having required the least total time per rat; and the groups with two and with one previous learning followed. In tables 27 and 28 are given respectively the average total time per rat and the rankings on this basis. The records of the different groups are shown graphically in figure 12.

TABLE 27

THE AVERAGE TOTAL TIME PER RAT BY GROUPS HAVING PREVIOUSLY LEARNED ONE OR MORE MAZES

	Maze A	Maze B	Maze C	Maze D	Maze E
Group having learned *one* preceding maze	5.56	4.65	12.81	16.20	3.27
Group having learned *two* preceding mazes	1.93	4.75	3.51	15.46	3.36
Group having learned *three* preceding mazes	2.01	3.09	4.55	8.20	1.63
Group having learned *four* preceding mazes	1.60	4.22	17.73	5.52	1.56

TABLE 28

THE RANKINGS OF THE GROUPS UPON THE MAZES, ACCORDING TO THE AVERAGE TOTAL TIME PER RAT

	Maze A	Maze B	Maze C	Maze D	Maze E	Av. Rank
Group having learned *four* preceding mazes	1	2	3	3	1	2.0
Group having learned *three* preceding mazes	2	1	1	4	2	2.0
Group having learned *two* preceding mazes	3	4	2	2	3	2.8
Group having learned *one* preceding maze.	4	3	4	1	4	3.2

The rankings according to the average errors per trial and the average time per trial are given in tables 29 and 31.

TABLE 29

THE RANKINGS OF THE GROUPS UPON THE MAZES, ACCORDING TO THE AVERAGE ERRORS PER TRIAL

	Maze A	Maze B	Maze C	Maze D	Maze E	Av. Rank
Group having learned *four* preceding mazes	1	1	3	3	1	1.8
Group having learned *three* preceding mazes	2	3	1	2	2	2.0
Group having learned *two* preceding mazes	3	4	2	1	3	2.6
Group having learned *one* preceding maze.	4	2	4	4	4	3.6

TABLE 30

THE RANKING OF THE GROUPS UPON THE MAZES, ACCORDING TO THE AVERAGE TIME PER TRIAL

	Maze A	Maze B	Maze C	Maze D	Maze E	Av. Rank
Group having learned *four* preceding mazes	1	3	4	1	2	2.2
Group having learned *three* preceding mazes	4	2	2	2	1	2.2
Group having learned *two* preceding mazes	3	1	1	3	3	2.2
Group having learned *one* preceding maze.	2	4	3	4	3	3.2

It is apparent from tables 26 to 30 that, as in the case of trials so in that of errors and time, an increase in the number of preceding maze-learnings does not necessarily and invariably result in a decrease in errors or in time. But that there is a tendency for the errors to decrease with the increase in the number of maze-learnings may be seen from the average rankings.

The Theory of Transfer

The foregoing paragraphs show that the degree of transfer is not a function of the serial position of the maze. It appears to be a function of the maze to which the transfer is made, irrespective of the position of this maze. Thus maze E, whatever its position, tends to be the one in which according to all the criteria the greatest savings are effected. The degree of transfer may be a function also of the maze or mazes from which the transfer is made. This became apparent in our search for the causes underlying the instances of negative transfer in trials on maze D. The transfer is not a function of the difficulty of the maze, for the E maze—to use it again as an example—was not the least difficult maze, as measured by the records of original mastery; and the B maze, which was the most difficult with respect to original mastery does not appear as the one in which the least savings were made.

In attempting an explanation of the presence and persistence of positive transfer, we may assume that the animal having learned one or more mazes and being introduced into a new one is to be looked upon as an organism

which has acquired some tendencies making for positive transfer and some making for negative. The kind and the degree of transfer may be viewed as the result of the interaction of these tendencies with the new situation.

When the hungry animal is introduced into the maze, its behavior indicates that it is controlled by the instincts of curiosity and timidity, the former being undoubtedly quickened by hunger. The instinct of curiosity accounts for the explorations of the animal, in the course of which it sooner or later reaches the food-box; and the instinct of timidity accounts in the main for the retreating movements, which are so frequent in the early stages of the learning. It would be baseless to say that there is never a retreating movement due to curiosity, or that curiosity never enters as a factor into the induction of such movements; nevertheless, the behavior of the animal when advancing through the maze in the earlier stages of the learning would seem explicable only on the ground that it is under the control of a combination of curosity and timidity, with curiosity in the ascendency. Its change of behavior into that of retreating is so precipitate and its movements back toward the food-box are so direct and rapid that it would seem due to timidity's gaining the upper hand over curiosity and coming to dominate the animal. The early cessation of these retreating movements in the course of the maze-learning would seem to indicate that the instinct of timidity soon recedes far into the background and becomes almost if not quite inactive. That this recession of the instinct of timidity carries over from one maze to another is apparent from the fewer retreating movements and their prompter cessation in a second maze than in the first. This recession of the instinct of timidity is a factor making for positive transfer.

Included among the kinaesthetic habits which the animal brings to the new maze, there are some tending to lead it into the true pathway and some tending to lead it into blind alleys. Since it is generally the errors made during the first few trials which become fixed and constitute the hindrance to be overcome in order to learn the maze,

it is the tendencies driving the animals into these blind alleys which are to be looked upon as the chief factor accounting for negative transfer. Conversely, the kinaesthetic habits acquired while traversing the true pathway under the influence of the exploring instinct of curiosity constitute one of the factors making for positive transfer.

The association which is formed between the animal's running through the maze to the end of the true pathway and its gaining access to the food-box is also a factor making for positive transfer. The only purpose for which the animals are taken from the cage before they begin their trials in the maze is to feed them, and before their first trial they have been taken out daily for a week and fed in the food-box of the maze. When they are placed in the maze for the first time, their behavior denotes the frustration of their food-securing movements and helplessness to deal with the new situation; but they need to pass through the maze only a few time and to gain ingress to the food-box every time before they will eagerly attack the problem presented to them by the maze, which is that of reaching its end and the food there as rapidly and easily as possible. What at first was a mere impediment to their obtaining food becomes consequently a part of the process of obtaining food, which begins with their being taken from the cage and ends with their entering the food-box. This association is no doubt formed by the end of the first maze-learning, and must affect favorably the promptness and persistence with which they attack the next maze, irrespective of the elements which affect unfavorably the learning of the second maze.

The practise in error-elimination which an animal has had while learning one maze would seem to exert a beneficial influence upon the learning of another. The blind-alley situation is one that is repeated in maze after maze, and calls for the same reaction in every instance, which is an about-face and retreat. This situation is the one unambiguous situation between the entrance and the exit of the maze, and the uniformity and repetition of response would seem to constitute what may properly be called practise in error-elimination; and we have encountered

evidence that uniformity of response would tend to appear in a uniform situation, in whatever maze this situation might occur.

The tendency to turn into blind-alleys which have been eliminated remains after the animal's last entrance into them, for not only do the animals occasionally reenter these alleys once or twice after they have been apparently avoided for good, but the swaying inward of their bodies as they pass certain blind-alleys into which they once regularly entered, sometimes bringing their bodies into contact with the far corner of the alley, would point to the same conclusion. The successful running of the maze must therefore include the overcoming of these tendencies to enter blind alleys, and this practise in error-elimination with its attendant resistance to the blind alleys once frequently entered cannot but leave its impress upon the reactions of the organism in any similar situation. In other words, the animal comes from its first maze-learning with a maze-habit formed, an integral part of which is this error-elimination activity including the habitual resistance to certain runways once frequently entered.

In seeking an explanation of the positive transfer of training, it would seem necessary to take into account this practise in error-elimination, while at the same time being careful not to read into the expression, "error-elimination," more than is implied in the discussion above. The rat which is learning its second maze forms habits under the combined influence of its instinctive reactions and the environment in which they are made, just as was the case in its first maze-learning; and under the spell of its exploring instinct it forms in the same manner habits of running into blind alleys. Its problem, from our point of view and little as the rat itself may realize it, is to eliminate these blind alleys, so as to reach the food-box as speedily as possible. The advantage which the rat that has learned at least one maze enjoys as compared with a rat that is attacking the same problem without having learned another maze beforehand is several-fold. The retarding influence of the instinct of timidity is not felt as strongly nor does it continue as long, the best evi-

dence for this fact being furnished by the large saving in the group's time of learning the second maze, as compared with the time of the control-group. In addition to this, the association between running the maze and the procurement of food is firmly fixed at the beginning of the maze-learning in the case of the rat that has learned a preceding maze, while this connection has to be formed by the inexperienced group in the course of the learning. Still again, and perhaps most important of all, is the practise in error-elimination. This does not secure the animal against entering blind alleys nor forming habits of doing so, neither does it assist the animal in finding the true pathway; but it enables the animal that has had this practise to eliminate more promptly its entrances into blind alleys.

The Correlations among the Records of Transfer through a Series of Mazes

It was found that a positive correlation existed among the savings in trials and errors, in trials and time, and in errors and time, effected by the various groups as they learned the various series of mazes; the savings being estimated on the basis of the average number of trials, the average total errors and the average total time per rat. A positive correlation existed among the savings when they were estimated on the basis of the average errors and the average time per trial, except in the case of that between trials and errors in the third group and that between trials and time, and errors and time, in the fifth group, in which cases it was negative. On this basis of estimation there were also two cases of zero correlation, those of errors and time in the second and in the third groups. The method of rank-differences was used in determining these correlations, and the two sets of figures are given in tables 31 and 32.

TABLE 31

THE CORRELATIONS AMONG THE RECORDS OF TRANSFER THROUGH A SERIES OF MAZES, ON THE BASIS OF THE AVERAGE TOTAL ERRORS AND AVERAGE TOTAL TIME PER RAT

Group	Series Learned	Trials and Errors	Trials and Time	Errors and Time
1	A to B, B to C, C to D, D to E	1.00	.70	.70
2	B to C, C to D, D to E, E to A	.80	.80	.60
3	C to D, D to E, E to A, A to B	.70	.80	.50
4	D to E, E to A, A to B, B to C	1.00	.40	.40
5	E to A, A to B, B to C, C to D	1.00	.80	.80

TABLE 32

THE CORRELATIONS AMONG THE RECORDS OF TRANSFER THROUGH A SERIES OF MAZES, ON THE BASIS OF THE AVERAGE ERRORS AND THE AVERAGE TIME PER TRIAL

Group	Trials and Errors	Trials and Time	Errors and Time
1	1.00	.40	.40
2	.80	.40	00
3	.80	—.40	00
4	1.00	.40	.40
5	1.00	—.20	—.20

IV. TRANSFER OF TRAINING BETWEEN A MAZE PARTIALLY LEARNED AND ONE COMPLETELY LEARNED

We have seen that there is always transfer of training when both mazes of a pair are completely learned, and that the transfer is positive. The inquiry may be made as to whether there is transfer of training when the first maze of the pair is only partially learned and the second completely learned.

In order to answer this inquiry, groups of rats were transferred from one maze to another after two, four, eight, or sixteen trials in the first of the two mazes, and also after the complete mastery of the first maze. The groups consisted of from seven to twelve rats, with an average of nine. The mazes used were the ones in which the greatest degree and the least of positive transfer of training had occurred in the last experiment considering the average of all the groups—mazes E and D respectively. The results are presented in tables 33 to 38, and graphically in figures 13 and 14.

TABLE 33

THE RECORDS OF GROUPS LEARNING THE D MAZE AFTER THE PARTIAL LEARNING OF THE E MAZE

	After 2 trials in E	After 4 trials	After 8 trials	After 16 trials	After complete mastery
Av. Trials....	25.29±2.90	28.43±6.20	26.10±7.46	16.20±7.46	20.86±4.00
Av. Errors per Trial.....	2.09± .31	1.94± .77	2.64± .63	1.07± .40	1.03± .35
Av. Time per Trial.....	.38± .08	.32± .06	.31± .03	.41± .17	.91± .25

TABLE 34

THE PERCENTAGES OF TRANSFER OF TRAINING IN GROUPS LEARNING THE D MAZE AFTER THE PARTIAL LEARNING OF THE E MAZE, ON THE BASIS OF THE AVERAGE ERRORS AND THE AVERAGE TIME PER TRIAL

	After 2 trials in E	After 4 trials	After 8 trials	After 16 trials	After complete mastery
Trials.....	— 3.73	—15.24	— 5.81	34.63	15.44
Errors.....	—10.60	— 2.65	—39.84	43.50	44.97
Time.....	75.11	.78.76	79.62	72.82	40.13

TABLE 35

THE PERCENTAGES OF TRANSFER OF TRAINING IN GROUPS LEARNING THE D MAZE AFTER THE PARTIAL LEARNING OF THE E MAZE, ON THE BASIS OF THE AVERAGE TOTAL NUMBER OF ERRORS AND THE AVERAGE TOTAL TIME PER RAT

	After 2 trials in E	After 4 trials	After 8 trials	After 16 trials	After complete learning
Errors.....	13.36	—18.27	—48.18	63.01	53.83
Time.....	74.37	75.73	78.40	82.37	93.07

TABLE 36

THE RECORDS OF GROUPS LEARNING THE E MAZE AFTER THE PARTIAL LEARNING OF THE D MAZE

	After 2 trials in D	After 4 trials	After 8 trials	After 16 trials	After complete learning
Av. Trials....	28.33±6.80	23.86±4.98	23.80±6.06	12.20±6.60	7.11±3.81
Av. Errors per Trial.....	2.05± .90	1.35± .44	1.99± .81	.68± .27	.31± .17
Av. Time per Trial.....	.33± .05	.28± .03	.33± .06	.38± .14	.46± .1

TABLE 37

THE PERCENTAGES OF TRANSFER OF TRAINING IN GROUPS LEARNING THE E MAZE AFTER THE PARTIAL LEARNING OF THE D MAZE, ON THE BASIS OF THE AVERAGE ERRORS AND THE AVERAGE TIME PER TRIAL

	After 2 trials in D	After 4 trials	After 8 trials	After 16 trials	After complete learning
Trials.....	—22.51	—11.72	— 3.03	47.19	69.22
Errors.....	—48.55	— 2.17	—44.19	51.01	77.69
Time.....	75.11	78.95	75.11	71.36	65.41

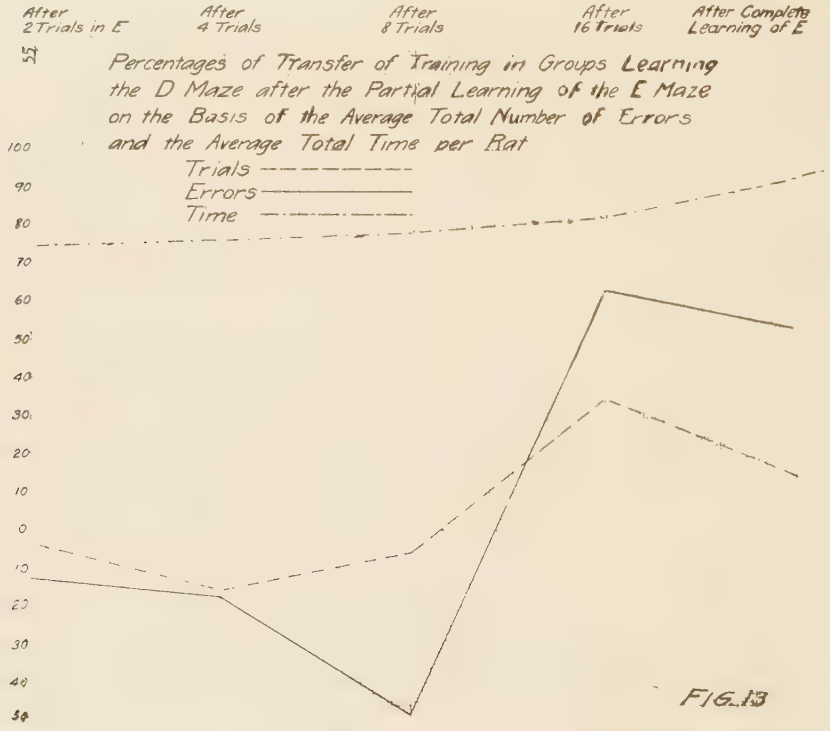
TABLE 38

THE PERCENTAGES OF TRANSFER OF TRAINING IN GROUPS LEARNING THE E MAZE AFTER THE PARTIAL LEARNING OF THE D MAZE, ON THE BASIS OF THE AVERAGE TOTAL NUMBER OF ERRORS AND THE AVERAGE TOTAL TIME PER RAT

	After 2 trials in D	After 4 trials	After 8 trials	After 16 trials	After complete learning
Errors.....	79.02	— 1.07	—44.36	73.96	93.09
Time.....	69.56	77.93	76.56	84.89	89.36

The most notable fact disclosed in tables 33 to 38 is that the transfer of training is negative, according to the trial and error-criteria in all the changes from one maze to another previous to the change after 16 trials. This is in accord with our study of the factors affecting transfer

(see pp. 34 ff.). As was there pointed out, it is the errors made in the blind alleys during the first few trials which become fixed and constitute the chief obstacle which the animal has to overcome in order to learn the maze. The transfer is negative prior to the change of mazes after the sixteenth trial for the reason that the factors making for positive transfer, and particularly the practise in error-



elimination, do not gain the ascendency over the negative tendencies until the latter stage of the learning process. Concerning the factors making for positive transfer, we may assert with confidence that the kinaesthetic habits tending to impel the animal into the blind alleys are formed at the beginning of the learning-process, and that the practise in error-elimination does not exert its beneficent effect until the latter part of the process; but we cannot

affirm with equal confidence at what part of the process the overcoming of fear and the association between running to the end of the maze and obtaining food begin to tell.

With regard to the transfer-effect according to the time-criterion, it will be observed that the degree of transfer did not increase regularly with the increase in the number of trials in the first maze of the pair, except in the average

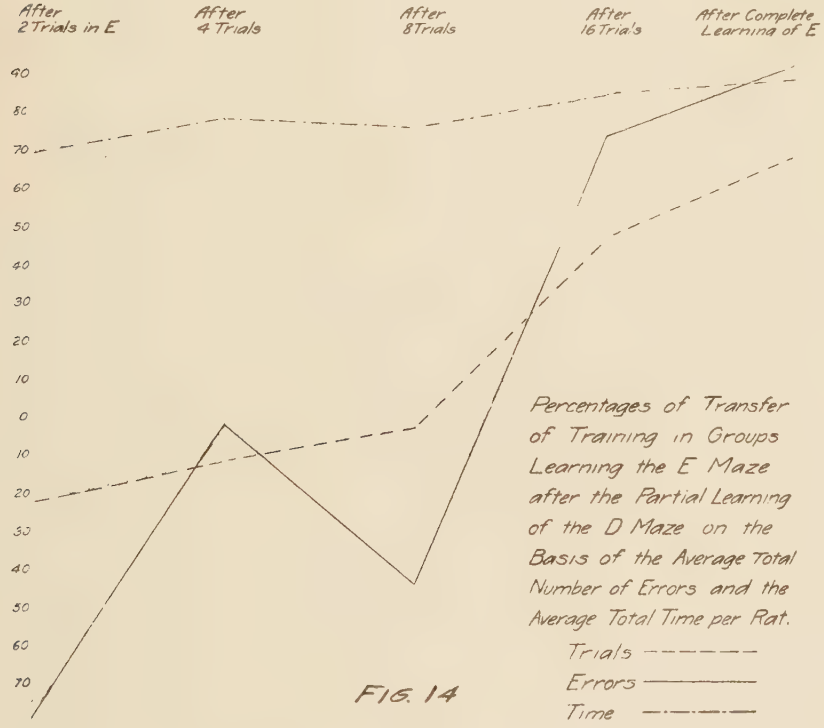


FIG. 14

total time per rat of the group carried over from E to D. But a regular increase of this kind was brought to light when the transfer was reckoned on the basis of the average surplus time required by the rats to run the mazes. This surplus time was obtained by subtracting from the average time per trial within a group the average time of the last trial made by the rats of the group that completely learned the same maze.

TABLE 39

THE PERCENTAGES OF TRANSFER OF TRAINING AS MEASURED BY THE SAVINGS IN SURPLUS TIME BY GROUPS LEARNING THE D MAZE AFTER THE PARTIAL LEARNING OF THE E MAZE

After 2 trials on E.....	81	After 8 trials on E.....	86
After 4 trials on E.....	85	After 16 trials on E.....	88
After learning E.....	93		

TABLE 40

THE PERCENTAGES OF TRANSFER OF TRAINING AS MEASURED BY THE SAVINGS IN SURPLUS TIME BY GROUPS LEARNING THE E MAZE AFTER THE PARTIAL LEARNING OF THE D MAZE

After 2 trials on D.....	76	After 8 trials on D.....	80.7
After 4 trials on D.....	80.6	After 16 trials on D.....	92
After learning D.....	96		

It is not surprising that the transfer in time should be positive throughout the entire series of transfers, for the first two trials are almost without exception the greatest time-consumers. The animals during these trials, and especially during the first, proceed very slowly and with every sign of extreme timidity. It rarely takes more than one or two successful passages of the maze for the animals' behavior in this respect to radically change, so that they proceed to their task with much greater speed. It is probably this increase in speed which, continuing through the four-trial partial learning and the eight-trial, secures slight increases in transfer of training.

V. TRANSFER OF TRAINING BETWEEN A MAZE COMPLETELY LEARNED AND ONE ALREADY PARTIALLY LEARNED

We have just considered the transfer of training as between a maze partially learned and a maze in which the rat has never run and which is completely mastered. Now we shall consider transfer of training as between a maze completely mastered and one which has been partially learned before the transfer is effected. The plan was to give two, four, eight or sixteen trials on D, then master E, and then return to D and complete its learning. A similar process was carried through beginning with E, then mastering D, and then completing the learning of E.

In the absence of any such data as are presented in the experiments herein described and by other experiments in the same general field, it might have been contended with some reason that the learning of the new maze would blot out the effects of the partial learning of the old, so that the animals would have to rebegin it. But, considering the evidence set forth above which is strongly in support of the positive transfer of training, the contrary presupposition might be formed, that the effect of such an interpolated maze-learning would prove beneficial. It might seem accordingly, on the one hand, a serious hindrance to the acquirement of a habit to break off the formation of that habit at a certain point in order to acquire completely a different habit before resuming practise upon the former. On the other hand, we have found ample evidence to believe that the beneficial effects of learning one maze can be carried over to the learning of another, and consequently we should expect that the animal will return to the learning of the original maze with some results of his training in the new maze which will prove available in the old. It becomes therefore a question of relative advantage and disadvantage, so that it may be asked with regard to the completion of the learn-

ing of the maze already partially learned: Does the advantage of the experience in the new maze, consisting in the formation of the association between the running of the maze and the satisfaction of hunger and in practise in error-elimination, counterbalance the disadvantage of bringing in another habit to confuse a habit in process of formation, especially when as in this case the habit which is being formed is the first maze-habit of the organism?

The groups which were used in the foregoing experiment in transfer after partial learning were carried back, after they had learned the second maze, to the mazes in which they had had two, four, eight and sixteen trials respectively, and were allowed to complete the learning. This furnished eight groups of rats, four groups of which while learning D were interrupted at these various points and taught E, after which they were returned to D and continued their learning of it; and four groups of which were trained according to the same plan, except that they began in E, were taught D, and then returned to E.

The effect from the point of view of trials was beneficial in all the transfers, except that in which sixteen trials were given in the first maze. This may be explained on the ground that in the last-named instance the habit was nearly formed, and much of the benefit of the sixteen trials were stored up—so to speak—in it; and when the new maze-learning was effected the disadvantage which it brought by inculcating particular kinaesthetic habits which conflicted with the nearly perfected maze-habit outweighed the advantage gained through the additional practise afforded by the new maze-learning in those activities which are beneficial in a general way irrespective of the design of the particular maze. The work which the group had done—to express it somewhat differently—by means of its sixteen trials was to a large extent undone by the new habit, and it took a number of trials to bring the group up to the efficiency it had attained before the interruption. While the new habit afforded exercise for the factors making for positive transfer, still not enough trials were saved as a consequence of this additional practise to make up for the trials lost through the conflict

of the habit completely formed in the second maze with the habit nearly formed in the first maze. Where the transfer was made after two, four or eight trials, the formation of the maze-habit had not progressed nearly so far, and a larger number of errors were being made than were being made by the sixteen-trial group when it was transferred. The consequence was that with these groups any interference with the imperfect maze-habit would not render futile, to all intents and purposes, many of the trials which had already been made, and that furthermore any interference with the imperfect habit, including a relatively large number of errors, would be not unlikely to correct an error instead of diverting the animal from the true pathway.

Table 41 presents the number of trials necessary to learn the maze—the trials before the interruption plus the trials after the interruption, and also the percentages of savings and losses. The savings and losses were computed by comparing the records thus obtained with the records of the control-group for the particular maze, and besides being shown in the table just named, they are presented graphically in figs. 15 and 16. Accordingly, the total number of trials in D before and after the learning of E were compared with the number of trials in D before

TABLE 41

THE AVERAGE NUMBER OF TRIALS REQUIRED IN A MAZE PARTIALLY LEARNED BEFORE THE COMPLETE LEARNING OF A SECOND MAZE AND COMPLETELY LEARNED AFTER THE LEARNING OF THE SECOND MAZE; AND THE PERCENTAGES OF TRANSFER OF TRAINING

Maze D		Maze E	
Trials	Percentages of Transfer	Trials	Percentages of Transfer
(Two Trials in Partial Learning)			
17. 9± 7.8	27.36	8.43±2.20	63.51
(Four Trials in Partial Learning)			
16.43± 4.61	33.39	15.70± .42	32.06
(Eight Trials in Partial Learning)			
23.00± 5.23	6.77	14.40±2.24	37.66
(Sixteen Trials in Partial Learning)			
29 .1± 4.70	—17.91	24.00±4.00	— 3.90
(Control-groups: Group 4 for D, Group 5 for E)			
24.67±12.67		23.10±7.10	

TABLE 42

THE AVERAGE TOTAL NUMBER OF ERRORS PER RAT MADE IN A MAZE PARTIALLY LEARNED BEFORE THE COMPLETE LEARNING OF A SECOND MAZE AND COMPLETELY LEARNED AFTER THE LEARNING OF THE SECOND MAZE; AND THE PERCENTAGES OF TRANSFER OF TRAINING

Maze D		Maze E	
Errors	Percentages of Transfer	Errors	Percentages of Transfer
	(Two Trials in Partial Learning)		
33.11	29.24	5.81	81.71
	(Four Trials in Partial Learning)		
37.62	12.89	24.81	—22.18
	(Eight Trials in Partial Learning)		
80.27	—72.14	29.81	6.18
	(Sixteen Trials in Partial Learning)		
80.61	—72.88	36.00	—12.92
	(Control-groups: Group 4 for D, Group 5 for E)		
46.63		31.88	

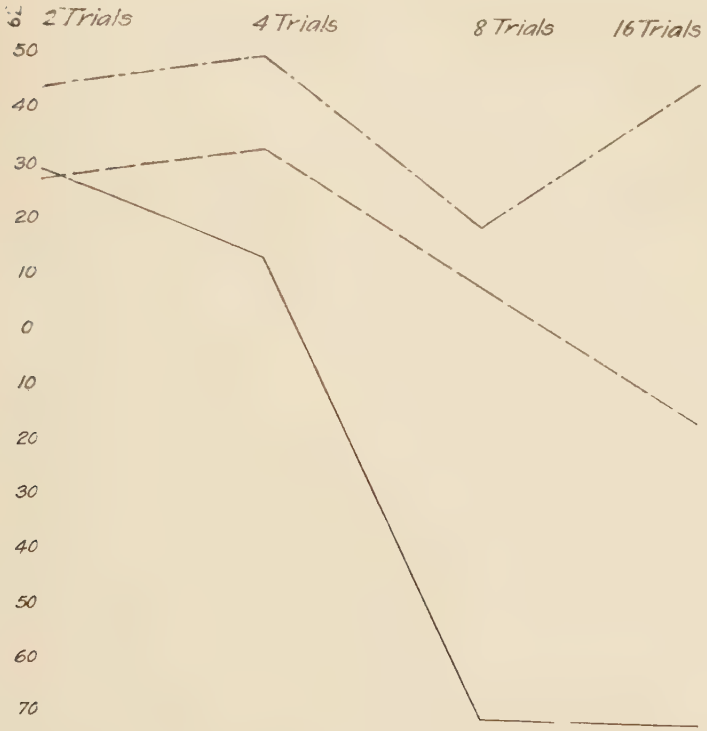
TABLE 43

THE AVERAGE TOTAL TIME PER RAT MADE IN A MAZE PARTIALLY LEARNED BEFORE THE COMPLETE LEARNING OF A SECOND MAZE AND COMPLETELY LEARNED AFTER THE LEARNING OF THE SECOND MAZE; AND THE PERCENTAGES OF TRANSFER OF TRAINING

Maze D		Maze E	
Time	Percentages of Transfer	Time	Percentages of Transfer
	(Two Trials in Partial Learning)		
22.91	44.24	32.52	— 5.86
	(Four Trials in Partial Learning		
19.55	50.55	51.32	—67.06
	(Eight Trials in Partial Learning)		
30.36	19.04	56.16	—82.81
	(Sixteen Trials in Partial Learning)		
20.08	46.46	30.49	.75
	(Control-groups: Group 4 for D, Group 5 for E)		
37.50		30.72	

and after the learning of E were compared with the number made by the control-group for D, which was group 4; and the same method was followed with respect to errors and time.

We cannot make, from the point of view of time, as broad a statement concerning the beneficial effect upon a maze-learning of interrupting it in order to learn another maze as was made concerning the same matter from the point of view of trials. The transfer in the E maze, with



The Percentages of Transfer of Training in the D Maze Partially Learned before the Complete Learning of the E Maze and Completely Learned after the Learning of the Second Maze.

Trials ———————
Errors ———————
Time —·—·—·—·—

FIG. 15

respect to time, was negative in three of the four changes from D to E. But there is nothing in this negative transfer to invalidate the findings of the experiments reported here and those reported elsewhere as to the generally positive nature of transfer, for this negative transfer was due to the fact that the animals made large time-records in the trials before the interruption, and then on being returned to the maze completed the learning in comparatively few

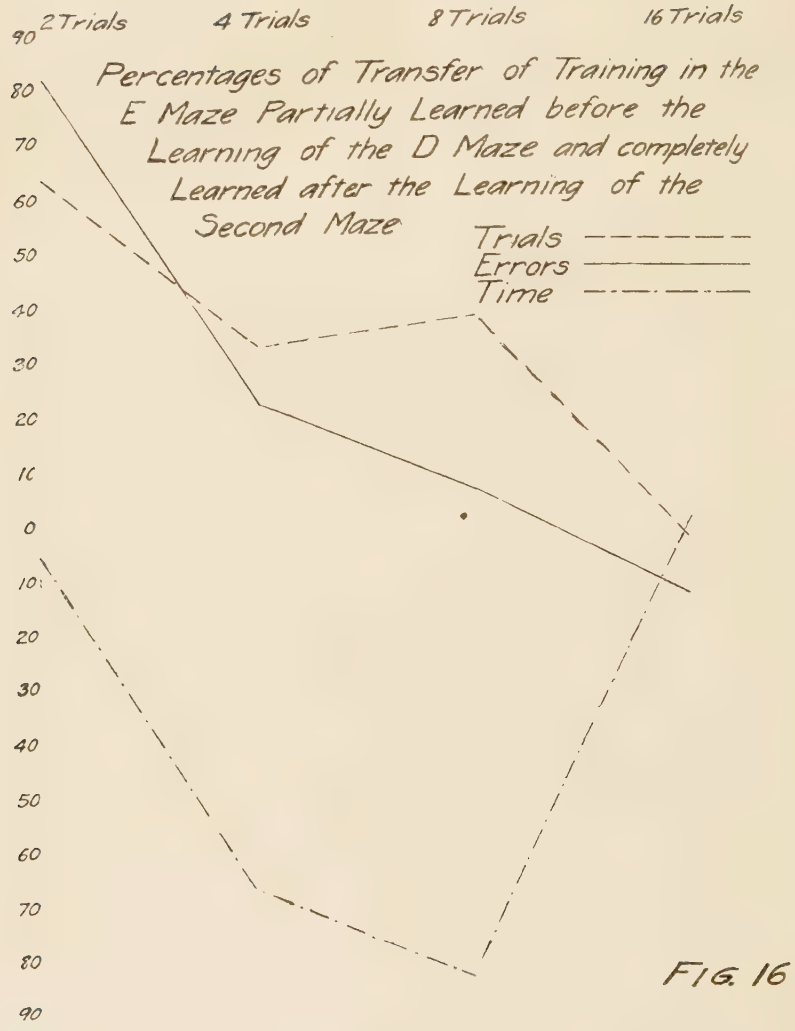


FIG. 16

trials, relative to the records of the control-group. The result was that, although the time-records of the trials following the return to the partially learned maze was low, still they were too few to counteract the high records made in the trials before the interruption; a large time-total therefore had to be divided by a small number of trials. For example, the average time per trial made by the group that was taken from the E maze after two trials

and brought back to E after having learned D was for the two trials 13.32 minutes, and for the remaining trials necessary to learn E but .28 of a minute; but the average number of trials necessary to complete the learning of E was but 6.43.

The negative transfer in errors after sixteen trials would seem to be due to the fact that a nearly perfect habit is interrupted in order to learn another maze; and the disconcerting nature of such a proceeding is denoted by the increased number of trials necessary to learn the maze, as compared with the control-group and by the increased number of errors per trial. It would seem that this principle is to be invoked to explain the negative transfer also when the partial learning consisted of eight trials.

The only criterion logically applicable here, when the two entire group-performances are compared with each other, is the trial-criterion, for as has been just indicated the favorable effect of practise as it is seen in the error and time-records of the group in the trials following its return to the maze whose learning has been interrupted is swamped by the high average made during the trials preceding the interruption. Accordingly, when we compare the records of the control-group with regard to errors and time with the records of the group whose learning is interrupted, we are not bringing together two learning processes which are analogous in these respects. The transfer in errors and in time, however, may be estimated by bringing into comparison the performances of the rats in the trial-group upon their return to the first maze after having learned the second with the performances of the rats in the control-group for the first maze, beginning with that trial of the control-group which corresponded with the first trial made by the trial-group upon its return. Thus in the case of the interruption after four trials, the first trial of the returning group after having learned the intervening maze would be its fifth trial upon the former maze; and the transfer which it has effected from the maze learned during the interruption may be estimated with reference to the record of the control-group beginning with its fifth trial and continuing to the end of the learning. In table 46

these records of the trial-group and of the control-group are placed side by side.

TABLE 44

THE RECORDS MADE UPON THE PARTIALLY LEARNED MAZE AFTER THE RESUMPTION OF LEARNING, COMPARED WITH RECORDS OF CONTROL-GROUP FOR SAME PART OF LEARNING

	Maze D		Maze E	
	Trial-Group	Control-Group	Trial-Group	Control-Group
	(Two Trials in Partial Learning)			
Trials....	15.92±6.06	22.67 .09	..... 6.43±2.20	21.10±7.14
Errors....	1.35± .48	1.66 .40	..... .36± .31	1.32± .32
Time.....	.22± .03	.71 .48	..... .28± .04	.43± .17
	(Four Trials in Partial Learning)			
Trials....	12.43± .56	20.67 7.09	.....11.71±6.10	19.10±7.06
Errors....	1.31± .29	1.43 .42	..... .61± .22	1.14± .30
Time.....	.24± .02	.38 .18	..... .26± .04	.32± .06
	(Eight Trials in Partial Learning)			
Trials....	15.00±6.75	16.67±7.26	..... 6.40±3.16	15.10±6.98
Errors....	1.55± .64	1.10± .64	..... .20± .32	.89± .22
Time.....	.24± .05	.44± .26	..... .25± .03	.30± .04
	(Sixteen Trials in Partial Learning)			
Trials....	13.10±4.70	8.67±6.14	..... 8.00±4.00	7.10±6.70
Errors....	1.06± .51	.65± .23	..... .30± .02	.40± .23
Time.....	.21± .02	.38± .18	..... .20± .01	.23± .03

All the records of the groups whose learning was interrupted showed a saving in that part of the learning which followed the return to the maze already partially learned, except the error-record of the group whose learning was broken into after the eighth trial in the D maze, the trial and error-records of the group whose learning was interrupted after the sixteenth in the D maze, and the trial-record of the group whose learning was interrupted after the sixteenth trial in the E maze.

The figures in table 44 help to bring out the fact, which has been already stated, that the negative result in the case of time, when the learning of the maze before and after the interruption is compared with the record of the control-group, is due to the small time-records made in the part of the maze-learning succeeding the interruption not being numerous enough to counterbalance the large time-records for the trials before the interruption.

These figures make plain the basis for the similar observa-

tion concerning the error-records, although in this case there are two exceptions. In the record of the group whose learning of the D maze was interrupted after the sixteenth trial, the negative transfer in errors in the part of the learning succeeding the interruption is to be ascribed to the same cause which produced the negative transfer in trials. In the part of the learning of the E maze that followed the interruption after the sixteenth trial, there was a small negative transfer in trials, but the causes producing it did not suffice to produce negative transfer in errors, although they did bring about the closest approach between the average errors of the trial and control-groups for any of the interrupted learnings in the E maze.

As a part of the present inquiry, the average error and time-records of the trial-group for the first three trials after its return to the maze already partially learned were compared with the records of the control-group for the corresponding trials. For example, the records for these first three trials after the resumption of learning by the group whose learning of the maze had been interrupted after the second trial were compared with the records of the control-group for the third, fourth and fifth trials upon the same maze. The figures setting forth this comparison are presented in table 45.

TABLE 45

THE AVERAGE ERRORS AND THE AVERAGE TIME PER TRIAL FOR THE FIRST THREE TRIALS AFTER THE RETURN TO THE MAZE ALREADY PARTIALLY LEARNED, COMPARED WITH THE CORRESPONDING RECORDS OF THE CONTROL-GROUP

	Maze D		Maze E	
	Trial-Group	Control-Group	Trial-Group	Control-Group
	(Two Trials in Partial Learning)			
Errors....	2.89	3.29	.67	2.30
Time.....	.26	1.30	.34	1.01
	(Four Trials in Partial Learning)			
Errors....	2.52	2.52	.81	2.00
Time.....	.27	.89	.30	.39
	(Eight Trials in Partial Learning)			
Errors....	2.90	2.00	.41	1.57
Time.....	.28	.50	.28	.37
	(Sixteen Trials in Partial Learning)			
Errors....	2.10	.86	.50	1.10
Time.....	.25	.52	.23	.29

The trial-groups all effected a large saving in the first three trials upon the resumption of the E maze. It may be said, in other words, that while they were learning the D maze following their two, four, eight or sixteen trials on E, they were continuing the learning of E, for on their return they showed both an improvement upon their earlier performances in E and a marked saving as compared with the control-group. Even more, some of the rats on their return to E ran that maze four times in succession without an error. Of those whose learning had been interrupted after two trials, three out of the seven rats composing the group made a perfect score upon their return to E, and none of these three had made an errorless run on either of their two former trials in E. Of those whose learning had been interrupted after four trials, one rat out of seven made a perfect score, so far as errors were concerned, and another made but one error in five trials; and neither of these had made an errorless run in its four previous trials. Of those whose learning had been interrupted after eight trials, six out of ten made a perfect score, and one made a single error in five trials; and among these was one rat which had made one errorless run, which was its first trial, and another which had made two errorless runs, on its fifth and sixth trials respectively. Of those interrupted after the sixteenth trial, two out of eight made a perfect score, one of these having made one errorless run, on its second trial, and the other no errorless runs.

If the general statement is justified that, while the rats of all four groups were learning D after having begun to learn E, they were continuing their learning of E at the same time they were learning D, there is equal justification for the statement that certain of these rats while being taught D completed their learning of E. It would be tempting to believe that these rats making errorless runs on their return to E had learned to recognize a blind alley at sight, if both their behavior in the maze and also the results of the experiments which have been made upon the rats' sensory control in the maze did not preclude such a belief. The present experiment does not furnish

the data for the solution of the problem, and any attempt at an explanation here would be but the advancement of conjecture.

The first three trials of the groups returning to the D maze after they have learned the E maze do not all show positive transfer, as is the case in the E maze after having learned the D. The group that had had two preliminary trials in D showed a saving both in errors and in time; but the group with four preliminary trials showed the same average number of errors as did the control-group, while those with eight and sixteen preliminary trials respectively made more errors than the control-group. With all four groups there was a constant saving in time.

VI. THE LEARNING OF TWO MAZES WHEN THEY ARE LEARNED ONE AFTER ANOTHER COMPARED WITH THE LEARNING OF THE SAME MAZES WHEN ONE IS PARTIALLY LEARNED, THEN THE OTHER COMPLETELY LEARNED, AND FINALLY THE LEARNING OF THE FORMER COMPLETED

After the learning of the first maze had been completed, as described in the last section, records were at hand giving the total number of trials, of errors and the time required for the mastery of the two mazes. These records enable us to compare the records of learning two mazes when these mazes are learned one after the other with the records

TABLE 46

THE LEARNING OF MAZES D AND E TOGETHER: THE AVERAGE TRIALS, AND THE AVERAGE ERRORS AND THE AVERAGE TIME PER TRIAL

1. Learning E and then D (Control) Total for E and D	
Trials	43.72±3.17
Errors	1.78± .20
Time	1.19± .26
2. Learning D and then E (Control) Total for D and E	
Trials	31.78±5.57
Errors	1.52 ±.32
Time	1.22± .48
3. Learning E after 2 trials on D, then completing the learning of D	
Trials	46.23±9.46
Errors	2.03± .58
Time	1.17± .64
4. Learning D after 2 trials on E, then completing the learning of E	
Trials	33.72±3.59
Errors	1.39± .73
Time	1.17± .32
5. Learning E after 4 trials on D, then completing the learning of D	
Trials	40.29±4.64
Errors	2.25±1.37
Time	1.14± .61
6. Learning D after 4 trials on E, then completing the learning of E	
Trials	44.13±4.71
Errors	1.19± .32
Time	1.17±1.32
7. Learning E after 8 trials on D, then completing the learning of D	
Trials	46.80±8.33
Errors	2.96± .40
Time	.79± .35
8. Learning D after 8 trials on E, then completing the learning of E	
Trials	40.50±7.33
Errors	2.53± .44
Time	1.73± .66
9. Learning E after 16 trials on D, then completing the learning of D	
Trials	41.30±8.30
Errors	2.12± .27
Time	.66± .31
10. Learning D after 16 trials on E, then completing the learning of E	
Trials	40.12±3.75
Errors	1.55± .25
Time	.96± .49

when one is partially learned, then the other completely learned and finally the learning of the former completed. The group which after learning the D maze as its first was carried over to the E maze in the course of the first experiment described above, having to do with the persistence and cumulation of transfer of training, served as the control-group for these mazes in this order. A special group of seven rats was trained in E and then transferred to D, giving a control for the learning of these mazes in this order.

The figures of the control-group are given in table 46, and after them the figures of the other groups learning the mazes according to the method indicated in connection with each group.

From the control-figures—those numbered 1 and 2 above—it will be apparent that the two mazes were mastered with less effort when the more difficult maze, judging according to the degree of transfer, which was D, was learned first. But the advantage of learning the more difficult maze first was counteracted if before learning it four trials were made upon the easier maze, to which the transfer was to be made. Moreover, when the order: sixteen trials in a maze, the learning of another maze, the completion of the learning of the maze in which the sixteen trials were made,—when this order was followed it mattered little whether the trials began in the more difficult or less difficult maze. The sixteen trials when made upon the more difficult maze resulted in a large saving in the easier maze, but this saving was counterbalanced by the comparatively great number of trials needed upon the return to the harder maze in order to carry its learning to completion. When the sixteen trials were made in the easier maze, the beneficial effect upon the learning of the second maze was far less marked, but this disadvantage was fully compensated for by the less effort needed to complete the easier maze.

If the series numbered 2, 4, 6, 8, 10 is viewed as one in which the order of the learning is from the D maze to the E maze, except that after the first maze-learning of the series the order is modified by the giving of a certain num-

ber of trials in the second maze, E, before the first is learned, then it will be observed that no maze-learning in this series subsequent to the first equalled the first, as far as the trial-criterion was concerned, while learnings 4 and 6 bettered it judging by the error-criterion, and 6 and 10 bettered it by the time-criterion. If the series 1, 3, 5, 7, 9 is viewed in the same way, as if the order E to D were the fundamental one and the learnings subsequent to it but modifications of it, we find that learnings 5 and 9 excel the first as judged by the trial-criterion; and that, although none of the after learnings equal the first from the point of view of errors, all surpass it from the point of view of time. It may be said therefore that there is no one method among all the arrangements, taking the D-to-E series and the E-to-D together, which enjoys signal preeminence. If it is said that the learning of the harder maze before the easier without any previous trials in the easier results in the best record according to trials, the learning numbered 4 is a very close second to it, and there are better arrangements according to the error and time-criteria. Nevertheless, there is an average advantage in learning the harder maze before learning the easier, from the point of view of trials and errors, as may be seen through the series in which the learning of D and then of E. is viewed as fundamental. When the time-criterion is applied, the series in which the passage from the easier to the harder maze is viewed as fundamental enjoys a striking advantage. These facts may be seen in table 47.

TABLE 47

THE AVERAGE RECORDS OF THE D-TO-E AND OF THE E-TO-D SERIES

	D-to-E Series		E-to-D Series
Trials	37.77±4.01	.....	43.60±2.25
Errors	1.64± .21	.....	2.03± .41
Time	1.44± .20	.....	.81± .21

VII. RELEARNING A MAZE AFTER HAVING LEARNED FOUR INTERVENING MAZES

It was possible, by carrying the groups of rats which had learned a series of mazes back to the first maze learned, to ascertain whether any beneficial effect of the first maze-learning appeared in the relearning of that maze after four intervening maze-learnings. Thus group 1, which learned the series from A to E, was brought back and retaught A; and group 2, which learned the series from B to A, was brought back and retaught B. It was considered that, if any beneficial effect of the original learning remained, the maze relearned would be mastered with less effort than any maze of equal or greater difficulty among the intervening four. If, conversely, one or more mazes of at least equal difficulty were learned more readily than the first maze was relearned, this would be accepted as evidence that the first maze, now being relearned, was practically speaking a new maze to the rats. The records of the relearnings may be found in tables 7, 9, 11, pp. 14 ff.

Looking at the relearnings from the trial point of view, we see that the A maze was relearned by its group more easily than any one of the intervening mazes was learned, except the E maze. This E maze, however, was an easier maze, according to the records of the control-group; although the ease of its mastery by group 1, as compared with the relearning of A was proportionately much greater than the difference in the difficulty attending the original mastery of the two mazes by the control-groups. The E maze was but 13 per cent easier as judged by the trial-criterion of the groups last named, but in the series of learnings which we are now considering the E maze was learned with 40 per cent less effort, by the same criterion. The group relearning the A maze saved 75 per cent as compared with the record of original mastery, but this same group learned E with a saving of 83 per cent as com-

pared with the control-group. This fact would seem to render unsafe the statement that the first group enjoyed any advantage in the relearning of A over and above the other mazes.

The B maze was relearned by the second group with an average of 7.5 trials, but the E and A mazes were learned with an average of 4.4 and 6.4 trials respectively. These mazes were less difficult than the B maze, which was the most difficult of all from the point of view of original mastery; but in these instances, as in the one just considered, the saving in the learning of the mazes as compared with the relearning of B was much greater than the records of the control-groups in these mazes as compared with the control-group in B. The A maze was 7.0 per cent easier according to the records of the control-group, but 15 per cent as shown by the group learning it in the series now being considered when this group's records in A and B are compared. The E maze was 20 per cent easier according to the records of original mastery, but it was 41 per cent easier in this connection. If the mazes A and E were as difficult as B, it would be defensible to say that no benefit from having learned B remained through the four intervening learnings and reappeared upon the relearning of B, since the group failed to evince any superiority in the relearning of B relative to the learning of an equally difficult maze. As it was, the group relearning B enjoyed a saving of 75 per cent as against the record of the control-group for A; and in learning E it saved 81 per cent, as compared with the control-group for E. Its saving in the B maze, as compared with its own record of original mastery, was 74 per cent. It is unwarrantable to see in the trial-record any survival of the benefit of the former learning of B.

The third group relearned the C maze in 6.2 trials. Although there was no learning of any intervening maze in fewer trials, the A maze was learned in nearly the same number—6.5 trials. The C maze was 39 per cent easier according to the control-groups, but its relearning was but 4.6 easier than the learning of A. The group relearned C with 62 per cent less effort than was needed in the original mastery, while it learned A with 76 per cent fewer trials than the control-group.

The fourth group learned the A maze, which was more difficult than the D maze, in fewer trials than were needed in the D maze, its saving in the A maze being 74 per cent and in the D maze 64. The fifth group failed to learn any of the intervening mazes in fewer trials than the relearning of the first maze called for, the nearest approach to the five trials in the relearning being the seven trials in C; but the C maze was much easier than the E. The fifth group was the only one that furnished any evidence in favor of the retention of the habit through a series of four mazes. With the other four groups, the weight of the evidence inclines to the other side.

When we consider error-records, we find that here also the weight of the evidence is against the retention of a habit through a series of this number of mazes. The third and fourth groups both learned mazes of greater difficulty than the original maze with fewer average total errors per rat than they made in the relearning of the original maze. The first group made the low average total of 1.31 errors per rat in relearning its first maze; but it made no errors in learning E. The second group made an average 3.97 per rat while relearning B, but it learned A with an average of 1.22 and E with an average of .31. It saved 94 per cent in errors as compared with its former learning of B, but it made 69 per cent fewer errors in A than in B, although A was but 29 per cent easier. It learned E with 92 per cent fewer errors than it made in A, although E was but 39 per cent easier. Coming to the fifth group, it will be found that its error-record in E was far better than its error-record in any of the other mazes of the series; and with regard to errors, as well as to trials and time, this group is the only one of the five that furnishes evidence of the retention of the beneficial effect of the original learning through four intervening learnings.

Looking at the matter from the point of view of the time-criterion, we find that the third and fourth groups learned one or more mazes of greater difficulty than the first of the series with a smaller time-average than the relearning of the first necessitated; and that the second group learned A, which was 7.8 per cent easier than B, in 37 per cent less time than was needed in B. With the first and fifth

groups, there was no maze-learning that rivalled the re-learning of the first maze, as far as the time-criterion was concerned. The evidence furnished by the time-criterion, accordingly, is more favorable than that furnished by the other criteria to the continuance of beneficial effect of the first learning throughout the series.

When the records are surveyed together, it is seen that only one group showed, according to all three criteria, signs of the retention of the beneficial effects of the habit formed in the first learning of the first maze. If the first and second groups showed evidences of the retention of the beneficial effect in time, they showed no unmistakable evidence of such benefit in either trials or errors. The most that can be said therefore is that the favorable results of having learned a maze do not always appear upon the relearning of it after the learning of four intervening mazes, irrespective of the patterns and order of the intervening mazes; but that there may be such patterns and such an order as taken together will result in a saving, according to one, two or three criteria, although within the limits of the present experiment there was but one series upon which the beneficial effect was seen as judged by all three criteria. It cannot be determined on the basis of these results whether, in those cases where the maze on being relearned was, to all intents and purposes, a new one, the loss of the benefit was due to the disintegration of the benefit was due to the disintegration of the habit through the lapse of time since its original learning, or to the interference of the habits acquired since the first; or if due to both, in what proportion to each.

VIII. SUMMARY OF RESULTS

The evidence furnished by these experiments supports the position that the learning of one or more mazes is usually beneficial with respect to the learning of another following them immediately, as determined by the fewer trials required and lesser time and smaller number of errors, compared with those of the control-group. There were no instances of negative transfer in either errors or time, but there were two instances of negative transfer in trials.

When two adjacent mazes contained identical parts, the more expeditious learning of the second was not due to the saving of errors in the identical part. Whether the identical part exerted a favorable influence which was effective in the saving of errors elsewhere than in the identical part is a problem that these experiments did not attempt to solve.

Although the average savings are higher when the transfer is from the more difficult to the less difficult maze, there is no ground for the statement that the transfer from the harder to the easier maze is in every instance higher than from the easier to the harder. The transfer from the easier to the harder may be greater.

The transfer of training was found to be not only positive but persistent, except in two instances of negative transfer in trials, throughout the learning of five series of mazes by a different group in each series. Although it was thus persistent, it was not cumulative; that is to say, it did not increase regularly with the increase in the number of previous maze learnings. There was no case in which the transfer, as determined by any one of the three criteria, increased throughout an entire series; and if there were a number of instances in which there was an increase for three maze-learnings, there were more successive decreases for three mazes than there were successive increases for three.

Looking at the matter from the point of view of the various mazes, rather than from that of the various groups, it was found that as far as the trial-criterion is concerned increase in the number of previous maze-learnings did not always result in an increase of positive transfer. According to the error-criterion, in the case of but two mazes did the favorable effect of prior learnings increase regularly. There was no maze in which the favorable effect according to the time-criterion increased regularly with the increase in the number of prior learnings.

It was found that a positive correlation existed between the savings in trials and errors, in trials and time, and in errors and time, though a series of mazes, estimated on the basis of the average number of trials, the average total errors and the average total time per rat; and that a positive correlation existed among the savings when they were estimated on the basis of the average errors and average time per trial, except in three instances.

The transfer-effect as between two mazes when the first is only partially learned did not become positive according to all three criteria until the transfer following the sixteenth trial upon the former maze, transfers having been effected after the second, fourth, eighth and sixteenth trials. The transfer according to the time criterion was positive after the change of mazes following two trials, and remained positive throughout the series, and nearly uniform when computed on the basis of the average time per trial. But when it was computed on the basis of the average surplus time per rat, it was both positive and cumulative.

When a transfer was made from a maze completely learned to one already partially learned, and the learning of the latter then completed, the latter maze was learned with a saving in trials when the partial learning consisted of two, four or eight trials, but the transfer was negative when the partial learning consisted of sixteen trials. The transfer of training, as shown in the average total number of errors per rat, was positive when the partial learning consisted of two or four trials in D, and negative when it consisted of eight or sixteen. It was positive when it consisted of two or eight trials in E, and negative when

it consisted of four or sixteen. As shown in the average total time per rat, it was positive throughout the entire series in which the preliminary training took place in the harder maze, and negative throughout the series in which it took place in the easier maze, except that when these sixteen preliminary trials took place in the easier maze there was a positive transfer of .75 per cent.

When two mazes were learned together, the first being partially learned, then the second completely learned, and finally the first completely learned, it was found that no one of these methods enjoyed a superiority according to all three criteria. The mazes chosen for this purpose were the ones in which the greatest degree and the least degree respectively of positive transfer had appeared in the preceding experiments. When the one in which the least had appeared and the one in which the greatest had appeared were learned in this order for purposes of control, it resulted in the two being learned with fewer trials and errors than when the order was reversed; the time was slightly greater, being an average of 1.22 as against 1.19. The advantage, from the point of view of trials and from that of errors, in learning the maze first in which the least transfer-effect had appeared was manifest throughout the entire series of learnings where this may be viewed as the fundamental order. The advantage from the point of view of time resides with the other order, in which the maze manifesting the greatest transfer was learned first.

When a maze was relearned after four intervening maze-learnings, only one group showed, according to all three criteria, signs of the retention of beneficial effects from the original learning of the maze. Two groups showed signs of the retention of a beneficial effect in time, but with no unmistakable evidence of such benefit in either trials or errors.